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ENERGY CONSUMPTION OPTIMIZATION FOR INFILL-BUILDING'S, ACCORDING TO ORIENTATION, IN AMMAN, JORDAN

By
Tala Samir Awadallah

Supervisor
Dr. Magdy Tewfik Saad, Prof.

This Thesis was Submitted in Partial Fulfillment of the Requirements for the Master's Degree of Architecture

Faculty of Graduate Studies
The University of Jordan

July, 2011

الجامعة الأردنيـــة
كلية الدراسات العليا

التاريـــخ: ٣١ / ٧ / ٢٠١١

نموذج رقم (١٨)
اقرار والتزام بقوانين الجامعة الأردنية وأنظمتها وتعليماتها لطلبة الماجستير

أنا الطالب: تالا سمير محمد عوض الله الرقم الجامعي: ٨٠٨٠٤١٥

التخصص: هندسة العمارة الكلية: الهندسة والتكنولوجيا

اعلن بأنني قد التزمت بقوانين الجامعة الأردنية وأنظمتها وتعليماتها وقراراتها السارية المفعول المتعلقة باعداد رسائل الماجستير والدكتوراة عندما قمت شخصيا" باعداد رسالتي / اطروحتي بعنوان: ....

Energy Consumption Optimization for Infill Building's, According to Orientation, in Amman, Jordan

وذلك بما ينسجم مع الأمانة العلمية المتعارف عليها في كتابة الرسائل والأطاريح العلمية. كما أنني أعلن بأن رسالتي /اطروحتي هذه غير منقولة أو مستلة من رسائل أو أطاريح أو كتب أو أبحاث أو أي منشورات علمية تم نشرها أو تخزينها في أي وسيلة اعلامية، وتأسيسا" على ما تقدم فانني أتحمل المسؤولية بأنواعها كافة فيما لو تبين غير ذلك بما فيه حق مجلس العمداء في الجامعة الأردنية بالغاء قرار منحي الدرجة العلمية التي حصلت عليها وسحب شهادة التخرج مني بعد صدورها دون أن يكون لي أي حق في التظلم أو الاعتراض أو الطعن بأي صورة كانت في القرار الصادر عن مجلس العمداء بهذا الصدد.

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COMMITTEE DECISION

This Thesis (Energy Consumption Optimization for Infill Building's according to Orientation in Amman, Jordan) was Successfully Defended and Approved on ---------

<u>**Examination Committee**</u>	<u>**Signature**</u>
Dr. Magdy Tewfik Saad, (Supervisor) Prof. of Architecture and Urban Planning The University of Jordan	------------------------------
Dr. Nabeel Al-Kurdi . (Member) PhD. in Planning and Housing in Developing Countries The University of Jordan	------------------------------
Dr. Wael Al-Azhari (Member) PhD. in Computer Aided Architectural Design The University of Jordan	------------------------------
Dr. Omaima Al-Arja (Member) PhD in Building Physics The Jordanian-German University	------------------------------

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الجامعة الأردنية

نموذج التفويض

أنا تالا سمير محمد عوض الله، أفوض الجامعة الأردنية بتزويد نسخ من رسالتي/ أطروحتي للمكتبات أو المؤسسات أو الهيئات أو الأشخاص عند طلبهم حسب التعليمات النافذة في الجامعة.

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DEDICATION

This thesis is dedicated to my beloved parents and siblings who have supported me through rough times and all the way since the beginning of my studies.

In addition, this thesis is dedicated to my adored children who were a great source of motivation and inspiration.

AKNOWLEDGEMENT

I am heartily grateful to Her Royal Highness Princess Sumaya Bint El-Hassan, the president of the Royal Scientific Society for her constant encouragement and personal inspiration in time of need.

I would also like to thank my supervisor, Dr. Magdy Tewfik Saad, whose guidance and support from the initial to the final level enabled me to develop an understanding of the subject.

In addition, I thank the examination committee members: Dr. Nabeel Al-Kurdi, Dr. Wael Al-Azhari and Dr. Omaima Al-Arja for their support and motivation.

In addition, I would like to show my gratitude to Dr. Tareq Al-Hadid, Eng. Aliaa Al-Ani, Ms. Susan Al-Baik, Ms. Rizan Farouq, Ms. Yasmeen Obaidat, Ms. Naela Al-Daoud, Dr. Erik Johansson, Dr. Djamel Ouhrani, and Eng. Meqdad Rababaa.

Lastly, I offer my regards and blessings to all of those who supported me in any value during the completion of the project.

Tala Awadallah

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LIST OF ABBREVIATIONS OR SYMBOLS

ABBREVIAVTION	
AFED	Arab Forum for Environment and Development
AREE	Aqaba Residence Energy Efficiency Project
BOMA	Building Owners' and Managers' Association
BREEAM	British Environmental Assessment Method
CO2	Carbon Dioxide
DEROB	Dynamic Energy Response of Buildings
DF	Daylight Factor
DOE	Department of Energy
EPBC	Energy Performance of Buildings Directive
GHG	Green House Gas
GJ	Giga Joules
HAP	Hourly Analysis Program
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
LEED	Leader ship in Energy and Environmental Design
MPWH	Ministry of Public Works and Housing
NERC	National Energy Research Center
PMV	Predicted Mean Vote
PPD	Predicted Percentage Dissatisfaction
QSAS	Qatar Sustainability Assessment System
RSS	Royal Scientific Society
SBCI	Sustainable Construction and Building Initiative
SC	Shading Coefficient
SHGC	Solar Heat Gain Coefficient
SNC	Second National Communication
TOE	Ton Oil Equivalent
UNDP	United Nation Environment Program
UN IPCC	United Nation Intergovernmental Panel on Climate Change
UPC	Urban Planning Council
USGBC	United States Green Building Council
UV	Ultraviolet
VLT	Visible Light Transmittance
VOC	Volatile Organic Compound
WFR	Window to Floor Ratio
WWR	Window to Wall Ratio

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ABSTRACT

This research focuses on finding optimal architectural design solutions of infill-building façades in Amman, Jordan. Four actual infill buildings oriented in four skewed cardinal orientations, North-East, North-West, South-East and South-West, were chosen to be simulated using DesignBuilder® software. According to literature review findings, 5 parameters were chosen in order to simulate and study the effect of their combinations in the four previously mentioned orientations. The parameters are: window to wall ratio (WWR)-(20, 40 and 100 percent), clear and low-e glass, single and double glazing, and availability of insulation and shading devices. According to the simulation results of 72 cases for each orientation, 288 cases in total, the following recommendations and conclusions were outlined:

1) Double glazing always have positive effect on heating demand regardless of the orientation of the main long façade, this was proven by empirical methods.
2) North-West and North-East orientations of main facades do not require any shading devices at all. However, shading devices are most important on high (WWR) facades facing South East, this was proven by empirical methods.
3) Complying with the requirements of the Energy Efficient Building Code (MPWH, 2010) is important for all buildings regardless of orientation.
4) 100 percent of (WWR) with clear single glazing should be banned for North-East and North-West facing infill-buildings.
5) The optimum (WWR) for all infill buildings, regardless of orientation, is 40 percent.

Keywords: Orientation, Energy Efficiency, Optimization, Thermal Simulation, Window to Wall Ratio, Thermal Insulation, Glazing.

CHAPTER ONE (I)

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1-1 Background:

There are numerous environmental impacts of construction activities. Globally, buildings consume 40 percent of the energy used annually. Close to 70 percent of the Sulfur Oxides produced by fossil fuel combustion are produced through the generation of electricity used to power homes and offices. Some 50 percent of Carbon Dioxide (CO_2) emissions- mainly in industrialized countries- are a result of the operation of buildings. (Dimson, 1996)

Significant gains can be made in efforts to combat global warming by reducing energy use and improving energy efficiency in buildings. The right mix of appropriate government regulation, greater use of energy saving technologies and behavioral change can substantially reduce Carbon Dioxide (CO_2) emissions from the building sector.

Resource consumption is increasing steadily in both developing and industrialized countries, especially fossil fuels. Although more pockets of these resources are discovered, and new technology might extract more than possible today, the rate at which the reserves of oil, natural gas and some metals are decreasing, means consumption most be controlled. Other, preferably renewable, resources must replace these traditional materials. (Der-Paterssian and Johansson, 2000)

A report from the United Nations Environment Program (UNEP) Sustainable Construction and Building Initiative (SBCI) pushes for a greater use of existing technologies like thermal insulation, solar shading and more efficient lighting and electrical appliances, as well as the importance of educational and awareness campaigns, in order to lower energy consumption levels in buildings. (UNEP, 2007)

1-2 Research Problem:

1-2-1 Orientation:

Based on Ouhrani, 1999, Rosenlund, 2000 and Johansson 2006 research and study results, it was found that the best orientation for buildings concerning energy consumption is orienting the long axis of a building to the East- West orientation, making the long facades facing North and South.

However, in the urban context of a city, especially in Amman, most of the commercial and mixed use buildings are "*in-filled*" on plots of land that face highways or main roads, which makes it obligatory for the main façade of the infill building to follow whichever orientation the property line lies.

Accordingly, the orientation of the main facade of the building is uncontrolled and cannot follow the rule of "*best-orientation-research-output*". Hence, certain solutions must be searched in order to optimize the uncontrolled orientation of the building energy consumption.

The findings of the research put out recommendations for regulatory bodies in order to enforce certain design measures for each of the four skewed orientations; South-West, South-East, North-West and North-East Orientations, or forbid the use of certain design options, also for different orientations.

1-2-2 Energy in commercial Infill-building:

A policy to reduce energy consumption and Greenhouse Gas emissions and to ensure sustainable development has to include measures to reduce the end use of energy in buildings. Consequently recommendations on policies for buildings are an important component of governmental regulations. (ECOFYS, 2010).

Energy, as consumption level and cost, was chosen as a study parameter that gets effected by orientation and location, as part of other parameters such as daylight, view and ventilation.

This is due to the importance of the energy issue in Jordan and the global climate change dilemma and the many effects that energy consumption does on the natural environment such as Ozone Depletion, Carbon Dioxide emissions and degrading non-renewable energy resource. In addition, energy modelling software's are more developed and experienced for energy than other relating parameters modelling software's.

Commercial and mixed use infill buildings in Amman, and not other types of public buildings such as schools or apartment houses; were chosen as case studies for the objectives of this research. Their restricted location and orientation make it vital to find ways to optimize the use of the restricted orientation so as to rationalize energy consumption. Local case studies would be chosen from buildings located on main commercial streets in Western Amman district, such as Al-Medina Al-Monawwara Street and Wasfi Attal Street. As a result, 4 skewed cardinal directions for case study buildings were chosen to be case studies of this research.

1-3 Significance of the Research

Commercial and mixed used buildings form a big bulk in the city of Amman, within the investment movement parallel to this development.

As part of the Building Sector energy consumption share in Jordan, which is 23 percent of total energy consumption, commercial and mixed use buildings consume a big share of the energy annually (NERC, 2007).

Hence, care should be taken when designing building envelope materials, shape, form, proportions and special additions such as shading devices. Therefore, it is the architect's responsibility to decide which optimum criteria to adapt in order to rationalize energy consumption in the commercial and mixed use buildings for each orientation.

Assuming solutions taken from case studies and conducted research, each solution should be tested in a special computer energy modeling software as a parameter in a typical infill building for all 4 skewed cardinal directions, adopting the climate data of the city of Amman, in order to find recommendations that best suit the location within the city.

The importance of the research is as follows:

1) The need to rationalize energy consumption in the growing building sector in Jordan, so as to reduce the escalating prices of imported crude oil and natural gas.
2) The need to create pilot projects in commercial buildings in order to serve as examples of best practice and applications.
3) The need to implement proper building material and design applications on infill building facades regarding their orientation, in order to minimize their negative impact on the surrounding environment and urban fabric.
4) the need to implement laws and legislations in regards to façade design and specifications for commercial buildings in Jordan.

1-4 Purpose and Objectives

Key indicators for sustainable design are: (Smith, 2006)

- Minimizing the use of fossil-based energy in terms of the energy embodied in the materials, transport and construction process and the energy used during the lifetime of the building.
- Designing to make maximum use of natural light whilst also being aware of its limitations.
- Making best use of passive solar energy whilst employing heating/ cooling systems which are fine-tuned to the needs of the occupants with air conditioning used only in exceptional circumstances.

Laws and regulations regarding ecological consideration are often put to limit pollution and decrease energy consumption for particular. Unfortunately, they are often not respected and lack enforcement and inspection mechanisms, which leads designers and builders to under estimate their impact and therefore not adopted. (JNBC, 2010)

The research aims into reaching sustainability in infill-buildings of Jordan. Therefore, the research objectives are as following:

1) Re-consideration of the design of infill-buildings in Jordan, since they have restricted orientation input resulted from their location on the planning map.
2) Comparing international and national case studies for infill-buildings in order to summarise successful solutions and criteria implemented, then apply them as parameters to measure in energy modelling.
3) Conducting energy modelling on typical infill-building design and performing parametric studies for each of the solutions summarised from the case studies in 4 skewed cardinal directions.
4) Drawing recommendations and results of the parametric study that aim at developing a list of optimum outcomes and criteria for each facade orientation, organized in ascending order, with the interest that these would be implemented in future infill-building development in Amman.
5) Minimising energy consumption in infill-buildings in particular, and the building sector in general.

1-5 Thesis Methodology and Structure :

Research methodology for this research constitutes of three main approaches:

1) Literature review to maintain a theoretical background, data collection and analysis related to the following:

   a) Environmental impact of energy consumption.

   b) The construction sector energy consumption, along with the identification of the building envelope parameters and their relationship with energy savings in relation with orientation.

   c) Laws and policies in regards to energy related regulations and systems.

   d) Climate data collection and analysis in the city of Amman, Jordan.

   e) Summary of energy consumption in the building sector in Jordan.

   f) International and national case study analysis with concern to orientation and energy optimization.

2) Simulation program application on four typical infill-commercial-buildings in Amman, for the purpose of creating a base case for bench marking. Thereafter, parametric studies have been done using concluded parameters of previous studies, followed by implementation into the simulation procedure in order to prepare a comparative study with the base case in each of the 4 skewed orientation cases.

3) Results and recommendations have been set out at the end of the study to serve, with the objective of the research, in finding ways to optimise energy consumption in buildings that have restricted main-façade orientation.

1-6 Terminology:

1 **Body-tinted (absorptive) glasses:** Body-tinted glasses have high extinction coefficient, low transmittance and high absorptance. The low transmittance also reduces the amount of daylight transmitted. The body-tint is produced by adding small quantities of metal oxides (iron, cobalt, selenium) which usually also give an apparent color to the glass– green, blue, bronze or grey. (Athienitis and Santamouris, 2002).

2 **Daylighting:** Daylighting is the use of light from the sun and sky to complement or replace electric light. (Ouhrani, 1999)

3 **Daylight effectiveness:** Daylighting effectiveness is assessed as a function of the illumination of the working or living space at the desired locations, and a glare index. The total amount of solar radiation incident on each room surface also depends on the solar reflectance of the room interior surface. The daylight factor (DF) is a commonly used parameter to assess daylighting effectiveness; it is the ratio of illumination at the point of interest (e.g. work plane) to illumination outside the fenestration due to unobstructed sky. (California Code, 2005).

4 **Environmental Impact:** The term environmental impact refers to disturbances that affect people's health and wellbeing and the value of the physical environment of the site with regard to the land, water, vegetation, animals and cultural relics if any. It also refers to the impact on the external environment, i.e. emissions to air, soil and water, and impoverishment of natural resources due to the energy and materials, which the building needs. (Swedish building research 3/98).

5 **G-factor:** or the Total Solar Heat Gain Factor (g) is defined as equal to the heat flux through the component under steady conditions for zero temperature difference between indoor environments, divided by intensity of solar radiation incident on the component. (O'Conner, 1997).

6 **Glare:** The excessive brightness from a direct light source that makes it difficult to see what one wishes to view. A bright object in front of a dark background usually will cause glare. Bright lights reflecting of a television or computer screen or even a printed page produces glare. Intense light sources, such as bright incandescent lamps, are likely to produce more direct glare than large florescent lamps. However, glare is primarily the result of relative placement of light sources and the objects being viewed. (MOPW, 2009)

7 **Heat transfer:** It is the net heat transfer across the fenestration system by conduction, convection and long-wave radiation. This is usually assessed as proportional to the window effective thermal conductance (U), measured with techniques such as the guarded hotbox method. (ASTM 1989).

8 **Insulating Glass:** it is a two or more pieces of glass spaced apart and hermetically sealed to form a single glazed unit with one or more air spaces in between (known also as double glazing). (MOPW, 2009)

9 **Light shelve:** The light shelf is a horizontal or an inclined plane projected over a view window. It may be external or internal one or both with a considerable reflective upper surface. As a shading device, it blocks the direct sun light from entering the room, thus reducing heat gain and glare. As a daylighting system it's used to improve uniformity and reflect light deep into the interior of a room.

The light shelf mechanism depends on receiving the direct sun light, and reflecting it to the ceiling and from there to the back of the room. Therefore, the light shelf's dimensions, location, reflectance, and room's surfaces reflectance and ceiling geometry are significant factors which affect the performance of the light shelf. From an another source, the light shelf is defined as a horizontal baffle placed at a certain height of the window opening, intended to provide shade below it and at the same time to reflect the light to the ceiling. In most cases the light shelf is fitted some distance up the window, dividing the window opening in two parts. (Lerum, 2008).

10 **Low-emissivity glass:** Low-e glass gives a year round energy savings and comfort by helping manage the sun's energy and the cooling system energy in your building. A low-e glass is coated with microscopically-thin, optically transparent layers of silver sandwitched between layers of antireflective metal oxide coatings. In the summer, Low-e glass let in visible sunlight while blocking infrared and ultraviolet solar energy that drives up cooling costs and damages curtains, window treatments, carpeting and furnishing. And in the winner, Low-e glass products offer greater comfort and reduced heating costs by reflecting room-side heat back into the room. (MOPH, 2009)

(Low-e) glass has a special coating on one surface which reduces its long-wave (for wavelengths greater than 3 µm) emissivity from about (0.9) for regular glass to about (0.1). The radiative heat transfer coefficient for the cavity in a double-glazed window is then dramatically reduced as described above.. Typical coatings consist of three layers – a thin metal layer (usually gold, silver or copper) sandwiched between dielectric layers of tin oxide. (Athienitis and Santamouris, 2002)

11 **Passive Building:** A passive building is a well insulated airtight building with mechanical inlet and extract ventilation. The air that is used for ventilation also warms the building. The heating demand in a passive building on the coldest day is 10-16 W/m2 depending on Climate zone and the surface area of the building. (Sustainability, 2008)

12 **R-Value:** The R-Value is the resistance to heat flow (R = 1/U), with higher numbers indicating better insulation. Glazing products usually list U-Value. Center-of-glass U-values are generally lower than whole-window U-values, which account for the effect of the frame and mullions. This property is important for reducing heating load in cold climates, for reducing cooling load in extremely hot climates, in any application where comfort near the windows is desired, and where condensation on glass must be avoided. (O'Connor, 1997).

13 **Spectral Selectivity:** Spectral selectivity refers to the ability of a glazing material to respond differently to different wavelengths of solar energy – in other words, to admit visible light while rejecting unwanted invisible infrared heat. Newer products on the market have achieved this characteristic, permitting much clearer glass than previously available for solar control glazings. A glazing with a relatively high visible transmittance and a low solar heat gain coefficient indicates that a glazing is selective. Spectrally selective glazings use special absorbing tints or coatings, and are typically either neutral in color or have a blue or blue/green appearance. (O'Connor, 1997)

14 **Solar heat gain coefficient (SHGC):** The technical definition of SHGC is the ratio of solar energy entering the window (or fenestration product) to the amount that is incident on the outside of the window. As with U-factors, the window frame, sash

and other opaque components, and type of glazing affect SHGC. (California 2005). A low SHGC reduces solar heat gains, thereby reducing the amount of air conditioning energy needed to maintain comfort in the building. A low SHGC may also increase the amount of heat needed to maintain comfort in the winter. (California Code, 2005).

15 **Shading Coefficient (SC):** The shading coefficient of a glazing material is the ratio of total transmitted solar heat to incident solar energy, typically ranging from 0.9 to 0.1, where lower values indicate lower solar gain. These indices are dimensionless numbers between 0 and 1 that indicate the total heat transfer of the sun's radiation. SC is the ratio of solar gain of a particular glazing as compared to a benchmark glazing (1/8" or 3 mm clear glass) under identical conditions. These properties are widely used in cooling load calculations. To convert between these properties, the following equation is used: SC= 1.15 x SHGC. (O'Connor, 1997)

16 **Surface Coating of Glass:** Surface coating applied on one or both surfaces may modify its long-wave or short-wave radiation properties. They are usually reflective or low-e coatings. (Athienitis and Santamouris, 2002)

17 **Thermal Bridge:** thermal bridge is known as heat leak, or short –circuiting. It is common that heat flows through a path of least resistance than through insulated paths. Insulation around a bridge is of little help in preventing heat gain or loss due to thermal bridging; the bridging has to be re-built with smaller or more isolative materials. For example, an insulated wall which has a layer of rigid insulating material between the studs and the finish layer. When a thermal bridge is desired, it can be a heat source, heat sink or a heat pipe.

18 **Translucent Glazing:** Translucent glazing's have low solar transmittance and they diffuse daylight; they are suitable for atria and skylights, where one does not use visual communication with the exterior. (Athienitis and Santamouris, 2002).

19 **U-Value:** The U-value is a measure of heat transfer through the glazing due to a temperature difference between the indoors and outdoors. It is the rate of the heat flow; therefore, lower numbers are better insulation. The unit of U-value is (W/m2·K, or Btu/h·ft2·°F). (Energy Efficient Building Code, 2010).

20 **Ultraviolet Transmittance:** Ultraviolet transmittance indicates the percentage of ultraviolet radiation (a small portion of the sun's energy) striking the glazing that passes through. Ultraviolet radiation (UV) is responsible for sunburn of people and plants, and contributes to fabric fading and damage to artwork. Many energy-efficient glazings also help reduce UV transmission. (O'Connor, 1997)

21 **Variable-Transmission Glasses:** Variable-transmission glasses are a new development that permits the building envelope to be used dynamically, responding to outdoor climate and interior thermal needs. Photochromic, thermochromic and electrochromic films may vary the transmittance. (Athienitis and Santamouris, 2002)

22 **Visible light Transmittance (VLT):** Visible light Transmittance (VLT) is a property of glazing materials that has a varying relationship to SHGC. (VLT) is the ratio of light that passes through the glazing material to the light that is incident on the outside of the glazing. Light is the portion of solar energy that is visible to the human eye. (VLT) is an important characteristic of glazing materials, because it affects the amount of daylight that enters the space and how well views through windows are rendered. Glazing materials with a very low (VLT) have little daylighting benefit and views appear dark, even on bright days. Higher (VLT) can result in energy savings in lighting systems. (California, 2005)

23 **Visible Reflectance:** or Daylight Reflectance indicates to what degree the glazing appears like a mirror, from both inside and out. It is the percentage of light striking the glazing that is reflected back. Most manufacturers provide both outside reflectance (exterior daytime view) and inside reflectance (interior mirror effect at night). All smooth glass is somewhat reflective; various treatments such as metallic coatings increase the reflectance. High reflectance brings with it low visible transmittance and all the interior disadvantages that may be associated with that characteristic. (O'Connor, 1997).

CHAPTER TWO (II)

LITERATURE REVIEW

(II)-1

CLIMATE CHANGE

2-1-1 Introduction:

a) General:

Scientists of the climate all agree on the temperature increase on earth, but the disagreement between them concerns its intensity and danger. Annual weather reports issued from different scientific entities predict a rise of two degrees in the earth temperature in the Arab world and the middle of Asia between 2030 and 2050. (Karzam, 2008)

The Main reason of climate change and the rise of temperature is due to human activities on the planet, contributing to the accumulation of greenhouse gas emissions produced from factories, transportation systems, and daily human activities concerning energy consumption and use. (Al-Jabery et.al. 2008).

b) Impacts:

The climate change challenge is one that is global both in its causes and in its solutions. It is ubiquitous in that almost all human activities contribute to the problem, and will also be affected by its impacts. (AFED, 2009)

This will therefore aggravate soil erosion problems, leading to the declination of Agricultural production and sometimes-natural disasters, such as total climate pattern changes and destructive wind blows, in addition to Widespread drought for long ties on the region, hence, the pollution of water, disease spread and consequently, the rise of death rate around the region. (Karzam, 2008)

Based on the findings of the Intergovernmental Panel on Climate Change (IPCC) and hundreds of references quoted in the 2009 Report of the Arab Forum for Environment and Development (AFED), we can categorically state that the Arab countries are in many ways among the most vulnerable in the world to the potential

impacts of climate change. The most significant of which are increased average temperatures, less and more erratic precipitation, and sea level rise (SLR), in a region which already suffers from aridity, recurrent drought and water scarcity. (AFED, 2009)

c) Strategies

Steering the third world countries energy through the rationalization of energy consumption, especially energy generated from fossil fuels, and decreasing the dependence on such resources that pollute the atmosphere with green house gas emissions, including carbon dioxide gases, by switching to the use of renewable energies represented by wind power, solar energy, geothermal and many other resources. (Karzam, 2008)

It is strongly advised that Arab regions and scientific regions within the country share and circulate green technologies and research finding more often and more efficiently in order to penetrate the world of a clean future for our children and children's children. (Karzam, 2008)

2-1-2 Global warming and Green House Gases

a) General:

The accumulation of the global warming impacts is caused by the steady increase in CO_2 gas concentrations increase generated by human activities. It is estimated that the concentration of CO_2 gas in the atmosphere in the twenty first century is approximately 380 ppm compared to a concentration of 280 ppm in the beginning of the Industrial revolution back in 1880. (Al-Jabery et.al. 2008).

A variety of gases collaborate to form a canopy over the earth which causes some solar radiation to be reflected back from the atmosphere, thus warming the earth's surface, hence the greenhouse analogy. The Greenhouse effect is caused by long-wave radiation being reflected by the Earth back into the atmosphere and then reflected back by trace gases in the cooler upper atmosphere, thus causing additional warming of the Earth's surface. (Smith, 2006)

b) Greenhouse gases:

The main greenhouse gases are water vapor, Carbon Dioxide Methane, Nitrous Oxide and Tropospheric Ozone (the Troposphere is the lowest 10-15 kilometers of the atmosphere). The main Green house gas is CO_2 and the main source of CO_2 (ca. 50 percent of all man-made emissions) is buildings. (Smith, 2006)

Since the industrial revolution, the combustion of fossil fuels and deforestation has resulted in an increase of 26 percent in Carbon Dioxide concentrations in the atmosphere. In addition, rising population in the less developed countries has led the burning of biomass. Methane is a much more powerful Greenhouse gas than Carbon Dioxide. Nitrous Oxide emissions have increased by 8 percent since pre-industrial times (IPCC, 1992).

Greenhouse gas emissions are a classical example of what economists call 'an externality': the costs are felt by everyone around the world, not just by the individuals or countries responsible for the emissions. The damage associated with climate change is not distributed proportionately according to emissions, as the burden is shared by those who contribute least to it. As an extra complication, the most serious damages will be not to present generations but to future ones, which do not have a strong voice at the negotiating table. (AFED, 2009)

c) Carbon Dioxide Gas Emissions:

Climate science tells us that we have pushed beyond "dangerous anthropogenic interference with the climate system", and are on the verge of committing to catastrophic interference. In this context, we argue for a stringent mitigation pathway (one that can only be achieved with international emergency program) that would give us a reasonable probability of keeping global warming below 2°C. (Baer, et. al. 2009)

This implies a pathway that would have global emissions peak in 2015, and then drop at a resolute 6 percent per year, to reach a level of 80 percent below 1990 levels in 2050. Along the way, CO_2 concentrations would peak near 425 ppm (with CO_2-equivalent levels reaching about 470 ppm) before they begin to fall. (Baer, et. al. 2009)

Adaptation sections define Jordan's priorities in linking adaptation to national policies for sustainable development. ((UNFCCC) 2009)

The percentage of contribution of gases in global warming is as follows: (Al-Jabery et.al. 2008).

64 percent	CO_2
19 percent	CH_4
11 percent	CFCs
6 percent	N_2O

This shows that the major contributor in global warming is the CO_2 gas.

d) Impacts

There are so many related impacts of green house gas emissions that we only touch on them here. Yet we see them illustrated daily in newspaper articles on the extinction of species, the increase in number and intensity of floods and cyclones, water shortages and the starvation that results from droughts. (Roaf, 2004)

The environmental effects of different energy sources are often debated. Transforming coal to electricity for example creates more CO_2 in the end-use than burning the coal directly. Different sources may also be more suitable for specific use. To take solar energy as an example: solar energy is excellent for hot-water production using simple techniques; however, the physical environment imposes restrictions and it is difficult to apply solar heating in high-rise buildings. (Rosenlund et.al. 2004)

e) Strategies:

What is certain is that we must act now to reduce CO_2 emissions globally and the one of the most effective sectors from which to achieve rapid reduction in emissions is buildings. (Roaf, 2004)

Because it displaces the use of fossil fuel it is estimated that passive solar design could lead to reduction in carbon dioxide (CO_2) amounting to 3.5 million tons per year in the United Kingdom (UK) alone by the year 2025 (DOE, Paper 60).

2-1-3 International Protocols

As a first step on the path of serious CO_2 abatement, an accord was signed by over 180 countries in 1997 in Kyoto to cut CO_2 emissions by 5.2 percent globally based on 1990 levels. It has to be remembered that back in 2007, the United Nation Intergovernmental Panel on Climate Change (UN IPCC) scientists stated that a 60 percent cut worldwide would be necessary to halt global warming, later endorsed by the UK Royal Commission on Pollution. The US has refused to ratify Kyoto but Russia has signed up which meant that the Treaty came into force in February 2005. The UK was on track to meet its 12.5 percent reduction target thanks to the gas power programme and the collapse of heavy industry. However ,these benefits have now been offset by the growth in emissions from transport. In 2003 there was a 1-2 percent increase in CO_2 emissions. Globally the year 2003 witnessed a significant rise in the age for the past decade. If aircraft emissions were also taken into account the situation would be substantially worse. (Smith, 2006.)

Despite the urgency of the climate change problem, the current international regime has been relatively ineffective. The Kyoto Protocol that came into force in 2004 limited the emissions of green house gases of a few states. And even those few

states were unable to reach that target. Environment ministers and officials failed to agree on a new climate treaty as a succession to the Kyoto Protocol at the Copenhagen Conference in December 2009. Greenhouse gases are still on the rise, the earth is more and more polluted. Nevertheless, part of the solution already exists to relief the earth from pollution: Renewable Energies. (Heydt, 2010)

2-1-4 Carbon Dioxide Gas in Jordan

Although Jordan does contribute a mere 20.14 million tons of Carbon Dioxide equivalent, it maintains strong commitment to the objectives developed by the international community for the integrated environmental and economic response to the threat of climate change. Global climate scenarios developed by the UN-IPCC have also indicated that Jordan and the Middle East will suffer from reduced agricultural productivity and water availability among other negative impacts. The nationally compiled findings of the Second National Communication (SNC) report in 2007 further reiterate the scientific evidence of the UN-IPCC and show the dynamics of Jordan's greenhouse emissions and where direct mitigation measures should be implemented.

(II-2)

ENERGY

2-2-1 Energy and Green House Gas emissions:

a) General:

Fossil fuel combustion and forest fires are the main resources of this gas. In fact, 80 percent of the CO_2 is generated from energy use in transportation and heating of buildings. (Al-Jabery et.al. 2008).

On the global scale, it is known that the use of fossil fuels has resulted in the emission of Carbon Dioxide, other greenhouse gases and sulfur. The Carbon Dioxide concentrations in the atmosphere is today about 375 parts per million, which is an increase of about 100 parts per million compared with just 100-200 years ago., due to human activities. (Formas, 2006)

Table (1) shows approximate Carbon Dioxide (CO_2) emissions per gigajoules (GJ) for selected fuels. (Habitat, 1991)

Table 2- 1: approximate (CO_2) emissions per gigajoules (GJ) for selected fuels.

Fuel	**CO_2 emissions (kg/GJ)**
Electricity from coal	230
Gas from coal	130
coal	90
Oil	85
Fuel wood	80
Natural gas	55

b) Strategy:

For CO_2 gas reduction, Energy efficiency strategies need to be considered. This is significant in terms of economic and environmental savings, as less fuel is consumed and less CO_2 is emitted. Hence this is a justified investment to improve

insulations for walls and the roof and the payback period is likely to be short. However optimizing the Wall to Floor Ratio (WFR) may be difficult in an existing apartment without altering the structure of the building. (Lund, 2008)

According to the Heinrich Boll Stiftung Conference recommendation governmental taxes should increase on products that contribute to the generation of Carbon Dioxide Gas, either in the process of its production or the course of usage. (Karzam, 2008).

It is estimated that stabilizing greenhouse gas emissions at between 45- 550 parts per million CO_2 will be required to avoid dangerous climate change. Ultimately stabilization- at whatever level- requires annual emissions be brought down to more than 80 percent below current levels. Green buildings will contribute to a very big part of lowering that percentage of CO_2 emissions. (Drivers, 2009)

2-2-2 Sustainability:

The historical experience of human progress shows that we should never seek development at the cost of wasting resources and damaging the environment. Development should be promoted along the road of high technological content, sound economic efficiency, low resources consumption, little environmental pollution, and full use of human resources. This is exactly what energy efficient and green buildings strives for achieving. (Drivers, 2009).

2-2-3 Energy Efficiency:

a) Background:

An oil spill off the California coast in 1969 sparked the U. S. Government into creating the first "Earth Day" in 1970. Earth Day events all over the country provided a way for widespread concern for the environment, awakened in 1962 by Rachel Carson’s Silent Spring, to find a voice. (Green Course, 2008)

Since 1970 there has been a steady increase in social awareness of the need to reverse humankind's negative impacts on the environment. Architects have been involved in this movement too, devising a multitude of different ways to supply the need for more environmentally friendly structures, buildings, and urban systems. (Course, 2008)

It was after the first energy crisis in 1973 that energy research took off. The International Energy Agency (IEA) was formed as early as 1974, and extensive energy research programs began in different countries. The goal was to reduce dependence on oil and to invest in domestic energy sources. The goal of IEA has expanded in time, and now it is the climate goal- to reduce the greenhouse effect of energy use- which is an important element in the whole globe. (Formas. 2005)

The oil crisis of the 1970s resulted in the rise of the solar house movement: homes built to use clean renewable energy from the sun.

In the 1980s came the next big shock- climate change. It was then that the rates of depletion in the Ozone layer and the increase in Green House Gases (GHG) and global warming became apparent.

The predictions made by the intergovernmental Panel on Climate Change in 1990 have been borne out by the steadily increasing global temperatures over the 1990s, the hottest decade on record. (Roaf, 2004)

b) Sources:

Primary energy sources for these needs may be (Rosenlund et.al. 2004)

- Fossil: petroleum, coal, LPG, natural gas
- Biofuel: wood, peat, vegetable oil, methane
- Nuclear
- Renewable: sun, wind, hydro.

These sources may be directly used to produce heat or mechanical power, or transformed into electricity. Production could be local small-scale or remote large-scale. Especially for the latter, there could be great losses in the distribution systems.

Renewable Energies do not only alleviate pollution, they also ensure independency from conventional energies. The instability of the price of a barrel in the last 35 years has had some dramatic outcomes on the international economy; end consumers have felt their energy consumption as a real preoccupation and burden. (Heydt, 2010)

c) Impact

The implications of the conservation alternative are thus enormously important to design professionals, as well as to the entire building industry; the more so because, as coherent as the arguments for conservation may be, relatively little has been actually accomplished to implement energy conservation practices compared to the range and magnitude of existing possibilities. (Watson, 1979)

2-2-4 Energy in Jordan

a) General:

At the heart of our climate change mitigation measures lies the issue of energy, which is considered as a challenge and an opportunity. Jordan is currently undergoing a paradigm shift in terms of energy policy planning. A combination of both necessity and conviction has worked together to drive a much needed vision for the development of renewable energy as a major contributor to the energy mix. (UNFCCC, 2009)

Energy-related activities have the dominant share of Green House Gas (GHG) emissions in Jordan. Emissions from this sector are classified into two main categories: Emissions from fuel combustion, and Non-combustion (fugitive) emissions.

The total emissions from the energy sector were 14911 Gg CO_2 eq., i.e., 74 percent of the total GHG emission of Jordan in the year 2000. Carbon Dioxide was the largest contributor (14714 Gg) at a percentage of 98.7 percent of the total energy sector emissions. ((UNFCCC) 2009).

b) Sources:

In Jordan, more than 200,000 solar water heaters, 7 MW of hydro power, 3.0 MW of pilot plant biomass electricity generation are currently in operation. In addition to that 100 kWp of photovoltaic systems, twelve wind turbines projects with a total capacity of 1620 kW were demonstrated in many remote applications. The National Energy Strategy aims at an increase of the share of renewable energy 10 percent of total energy supply by 2020 which corresponds to an investment for generating 300 MW from wind and 300 MW from solar systems. (Khraisheh, 2010).

The fuels consumed by this category are LPG (for cooking), Kerosene (mainly for space heating and cooking) and diesel (mainly for space heating). The residential activities accounted for 66.9 percent (1858.3 Gg) of the total CO_2 emission of this other sectors category (2779.8 Gg), followed by the commercial/institutional activities which accounted for 19.4 percent and finally agriculture fuel combustion activities which accounted for 13.7 percent. ((UNFCCC) 2009).

c) Challenges:

The National Energy Strategy 2008-2020 identifies a target of 10 percent of renewable energy by the year 2020 comprising a ten-fold increase from the share of 1 percent in 2007. This transition will require capital investments, technology transfer and human resources development to produce a solid base to maintain and

enhance this positive change pursued through the modified energy policy. The success of Jordan's mitigation portfolio will highly depend on a smooth system of technical and financial support to deploy the best available technologies in sectors of energy, transport and waste management, in particular. ((UNFCCC) 2009).

One of the main challenges in the energy sector in Jordan is the continuing increase on energy demand. For fossil fuel demand, it is expected to exceed an annual growth of 3 percent. On the other hand, the demand on electricity is expected to exceed 4 percent growth annually. (GTZ, 2007)

Key barriers to energy efficiency are: (GTZ, 2007)

- lack of knowledge by energy users of the benefits of energy efficiency
- lack of expertise to develop energy efficiency projects
- high initial implementation cost
- lack of suitable financing mechanisms, as banks lack experience and awareness in energy efficiency and need assistance on risk analysis and mitigation to achieve bank ability
- lack of consistent institutional frameworks.

(II)- 3

ENERGY IN THE CONSTRUCTION SECTOR

2-3-1 Environmental Impact

The construction industry is a major polluter of the atmosphere. Air pollution occurs at different levels: (Der-Paterssian and Johansson, 2000)

1) Local level: emission of dust, fibers, particles and toxic gases.
2) Regional level: emissions of Sulfur and Nitrogen Oxides.
3) Global level: emissions of Greenhouse Gases and Ozone-Depletion substances.

The construction sector plays a significant role in economic development in every country. It provides the direct means to the development and expansion of economic activities and is, at the same time, a major consumer of physical and natural resources and a polluter of the environment. Over the last 30 years, the environmental impact of human settlements development, including construction activities, has grown dramatically due to the sheer increase of the world population and greater industrial and human activity. (Der-Paterssian and Johansson, 2000)

Buildings, as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and other natural resources. The close connection between energy use in buildings and environmental damage arises because energy intensive solutions sought to construct a building and meet its demands for heating, cooling, ventilation, and lighting, which causes severe depletion of invaluable environmental resources. The continuous increase in the consumption of energy is not only consuming an unsustainable amount of fossil fuel but it also delivers huge amounts of air pollution, which is linked to the global warming and Green house effect resulting in Ozone depletion. (Kamal and Roorkee, 2009).

2-3-2 Energy in buildings:

a) Background:

The energy efficiency of a building is dependent on the performance of the total building system, and in other words, the energy performance of the building system. Buildings alone consume more than 40 percent of the final energy consumption within the European Union (EU), and contribute to a corresponding amount of Carbon Dioxide (CO_2) gas, a Greenhouse Gas scientifically proven to contribute to the global warming phenomenon. (IIIEE Reports, 2003)

Some 35M new housing units are needed annually- or 95 000 units' daily to meet the world's urban housing need. Therefore, it is essential to pay attention to the kind and quality of the housing units provided, and what better solution is than green environmentally friendly buildings. (World Bank, 2008)

The US North- East blackout of 2003 affected power generation, water supply, trains, air services, fuel supplies at gas stations, oil refineries, communication systems, and large numbers of factories were closed. That is why it is important to passively design building in order to lower our dependence on technology. (Drivers, 2009).

In Barcelona, an ordinance introduced in 2000 led to a 10-fold increase in the number of solar water heaters in three years and had repercussions through Spain. Available solar energy in Barcelona equals about 10 times the city's energy consumption. (Drivers, 2009).

The same situation can exist here in Jordan because of its exceptional weather circumstances that can benefit from solar energy, and green buildings promote this concept. (Author).

b) Categories of consumption:

Energy is consumed in the construction sector in many ways and types, these are as following:

1) Operational energy

"End-use" energy, that required at the building operate its systems, is usually accounted for by the "purchased" cost of fuel and electricity. It is purchased energy costs, the costs in the marketplace, the market cost of energy may not accurately represent differences in the primary expenditure of "source energy" required to produce, convert, and transport that energy to the building. For fossil fuels and supply it to the building, for electric resistance heating requires three to four times the source energy as that used by a gas-or oil-fired burner at the building itself. (Watson, 1979)

The energy consumed by a commercial building during its lifetime should be kept to a minimum. The benchmark is currently 100 kW/m² but this will become more stringent as pressure mounts to limit carbon emissions. Techniques such as high insulation, thermal mass, passive and active solar optimization, natural light, natural ventilation, on-site electricity generation and seasonal energy storage are components of the green agenda. (Smith, 2006)

2) Embodied energy

Energy is used in constructing buildings and in producing construction materials and components. "Embodied energy" is a measure of energy required to manufacture and put into place a particular building component or construction system. Up to 5 percent of the United States'

energy consumption has been ascribed to energy embodied in construction, and this can be readily reduced by improvements in design and manufacturing processes. (Watson, 1979)

Minimizing the embodied energy will contribute to minimizing the carbon content of materials in the extraction, manufacture, delivery and construction stages. This can be possible by promoting the use of recycled materials and designing for reuse after demolition. (Smith, 2006)

3) Transport energy

Avoiding unnecessary transport journeys during construction in terms of the delivery of materials and the removal of site waste. Access to good public transport should be a prime requisite in deciding location. There have been instances where corporation have relocated from city centers accessible only by public transport to highly energy efficient offices on out of town sites. This has encouraged a much greater use of cars resulting in a net increase in Carbon Dioxide (CO_2) emissions. (Smith, 2006)

c) Energy in the building's lifetime:

The construction sector is a major user of energy. Energy is required for manufacturing materials, for transport and for construction of buildings. Apart from this initial energy use there is also need for energy to operate buildings, contributing to more than 85 percent of the energy used through the whole lifetime of the building. See figure (1).

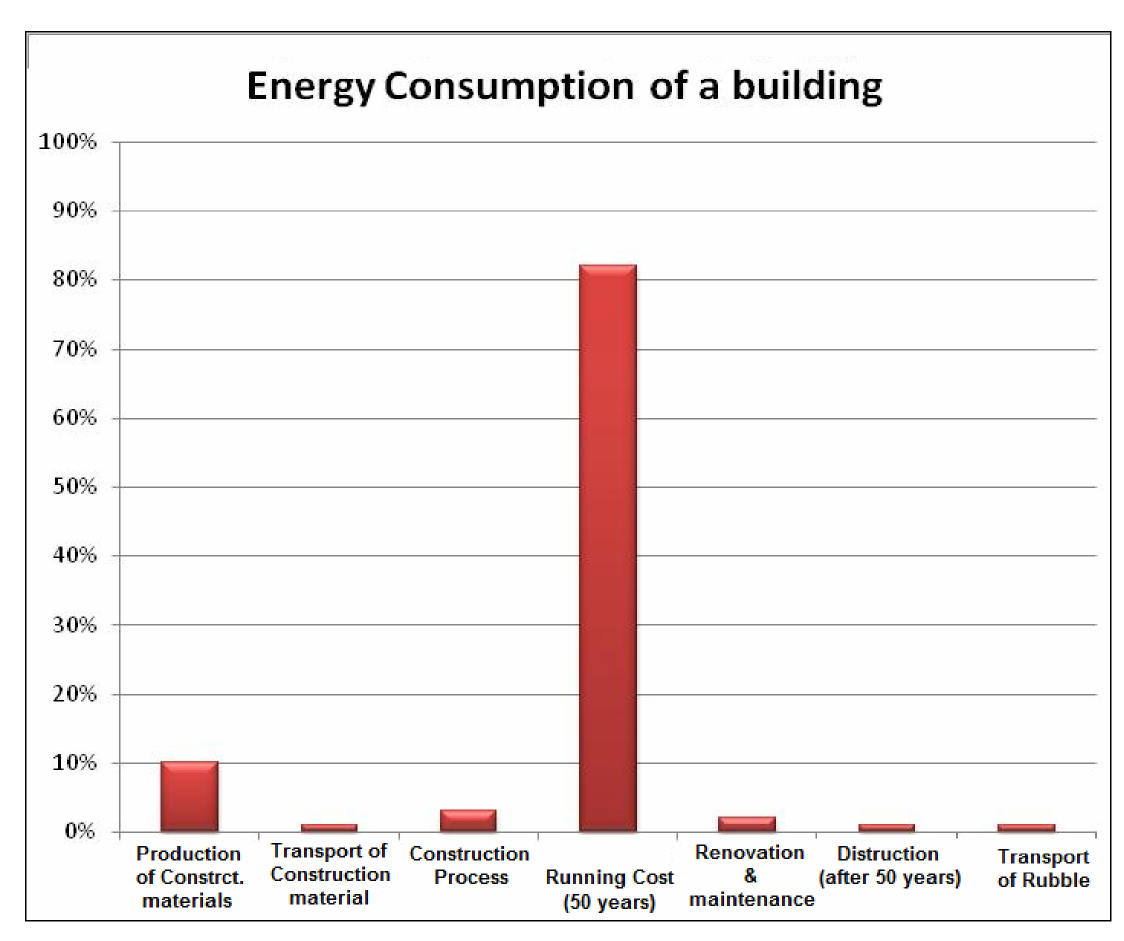


Figure 1: Energy consumption in a building's lifetime (Ouhrani, 1999)

A considerable amount of energy is used in buildings during their lifetime. This energy is required for heating, cooling, ventilation, lighting, cooking and other domestic activities. The energy use patterns inside buildings vary a great deal according to occupants behavior, type of structure and location of buildings. (Paterssian et.al 2000)

It is obvious that buildings are large energy consumers under any climatic context and variation; this of course will reflect on total building running costs, and we may consider that energy and fuel probably could contribute largely to the overall running costs for any building.

Fuel consumption for any building may take several forms, types and patterns of use this follows the type of building and occupation periods and type of operating systems in a building.

2-3-3 Energy Consumption in the Commercial Sector:

a) General:

Commercial building include public and private office buildings, retail stores, hotels and motels, hospitals and nursing homes, warehouses, schools and colleges, and recreational, cultural, and other institutions. These are the facilities that the utility companies include in the "commercial costumer" class. (Watson, 1979)

b) Energy consumption:

The commercial sector will account for an even greater portion of the national energy use and peak electric demand, assuming the same degree of conservation applied equally to all customer classes. However, opportunities for energy conservation and peak electric demand control are more immediate in the commercial sector with available hardware, building materials, mechanical and electrical equipment and systems, and building operational practices, than in the residential and industrial sectors, although many of the same energy conservation measures and energy management programs are effective in all building types. (Watson, 1979)

This is especially worrying in the commercial building sector because of the rate of increasing use of electricity, as compared to heat or primary fuel. Therefore, in order to reduce greenhouse emissions, energy efficiency issues are addressed by a reduction in the energy consumption of buildings and the enhancement of energy performance. (IIIEE Reports, 2003).

Offices in particular have traditionally users of energy because, in relation to all other costs, energy is a relatively minor fraction of the total annual budget. In many cases the major electricity cost is incurred by lighting. The 1980s sealed glass box may use energy at a rate of over 500 kWh/m²/year. Currently, best practice is in the region of 90 kWh/m²/year. The aim of the architect under the sustainability banner is to maximize comfort for the inhabitants whilst minimizing, ultimately eliminating, reliance on fossil-based energy. (Smith, 2006)

Every year the Building Owners' and Managers' Association (BOMA) reports the air-conditioning operating costs of over 125 million ft^2 of office buildings on a city-by-city basis. (Watson, 1979)

In residential buildings, the vast majority of energy use is for climate control, so that the thermal quality of the building and the severity of the weather become the predominant influences on energy use. On the other hand, In nonresidential buildings, subject of this thesis, the reasons for energy use become far more complex. The general reasons are: (Watson, 1979)

- Function of Building: The function of the building determines the energy-consuming equipment within the building, and secondarily, can influence the heating and/or cooling system type and thereby its energy intensity.
- Type of Control: The type of con*t*rol of the heating and cooling systems (and may process systems) can influence energy use to a great extent.
- Energy Distribution: Energy needed to distribute energy is that which is used to move heating and/or cooling energy through a buildings from its source to its end-use, usually the occupied spaces. This is usually done by pumps or other equipment.

- Hours of Operation: Since most nonresidential buildings are not used 24 hours per day, the hours of operation for the heating and cooling systems will have a significant influence on energy use, depending on solar hours and night time where heat gain and loss differs, in addition to indoor thermal comfort needs dependence on time of operation.
- Ventilation Rate and Thermal Quality of Building are also important in non-residential buildings.

2-3-4 Energy Performance:

Due to the fact that one third of national total annual energy consumption is consumed in buildings, it is estimated that a substantial energy savings can be achieved from a conventional building design through careful planning for energy efficiency. Optimizing the façade of a building, supporting structure assisted thermal storage or optimizing heating, ventilation and air conditioning (HVAC) systems would be rather beneficial to save investments or running costs but also to reduce the energy use in buildings. (Hopfe and Hensen, 2005).

As a research topic, building energy performance is placed within the field of engineering or at the scientific end of the art and science concept of architecture. Consequently, experimental methods are predominantly used when investigating building energy performance. It is still useful, and sometimes necessary, to speculate at some length about the application and appropriateness of methods borrowed from other disciplines, such as methods frequently used in the social sciences. (Lerum, 2008).

(II)- 4

THE HASHIMITE KINGDOM OF JORDAN

2-4-1 Background

The Hashemite Kingdom of Jordan is located between 29° 11' to 33° 22' North and 34° 19' to 39° 18' east. Altitude ranges from about -415 m (below mean sea level) at the surface of the Dead Sea up to 1845 m at top of Jabal Um AdDani. Jordan is known to have a wide variation of landscape components, hills and valleys, even and uneven land, therefore, different variations of climate are experienced all over Amman throughout the year.

2-4-2 Climate:

a) General

The climate of Jordan is predominately of the Mediterranean type, which is characterized by a hot dry summer and rather cool wet winter, with two transitional periods the first starts around October and the second around mid of April. Most of the precipitation falls in the form of rain or drizzle, snow may fall on highlands and hail is frequent during thunderstorms. Precipitation falls during rainy season (October- May), but about 75 percent of precipitation falls during winter season, which extends from December to March. (UNFCCC) 2009

b) The city of Amman:

Amman, the capital of Jordan, is a mountainous city which enjoys four seasons of excellent weather when compared to other places in the region. Summer temperatures range from 28 °C to 35 °C, but with very low humidity and frequent breezes. Spring and fall temperatures are extremely pleasant and mild. The winter sees nighttime temperatures frequently near 0 °C, and snow is known in Amman. (UNFCCC, 2009).

Being on a high altitude, with 35°E longitude and 32°N latitude, climate can be cold to very cold in winter and warm to hot in summer, with south-west and south winds through the year, and quite a good amount of rain fall compared to the hot-arid climate of Jordan.

The lowest part of Amman is presented by the amphitheatre station in down town with an altitude of 730m above sea level, and the highest (approximately) is presented by the Jordan University station, 980m above sea level, where the case studies (of this thesis) are located.

The data collected was taken for the Jordan university station, which has the same altitude and nearly the same latitude as the original position of the real case studies of this thesis. This data was extracted from the Jordanian Metrological climate data, accumulated until 2003.

The values were put in a certain excel sheet template as in table (2). This template was developed by the Housing Development and Management Department at Lund University, Sweden, to link climate data with visual charts and graphs generated by the values filled in the excel sheet, see figures (2) to (5). This data also generates, by the developed template, Mahoney tables and Givoni charts for the specified climate data. See Appendix B.

Mahoney Tables are most useful for determining general building design criteria and concepts based on the climate input. It gives outputs and design suggestions in regards to layout, indoor spacing, air movement requirements and shape of roofs, in addition to detailed recommendations on size of openings, position, shading needed and other climate related elements. See table (3).

Table 2: Excel Sheet Template for Climate data, University of Jordan Station, Amman (Jordanian Metrological Department, 2003)

Station:	**Amman, University of Jordan**
Source:	**Meteonorm, Jordan Climate Handbook**
Data collected by:	*Tala Awadallah*
Latitude:	32 °
Longitude:	35
Altitude:	980 m

Solar radiation

Sunshine (hours/day)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
real	5,10	5,90	7,00	8,30	10,40	11,90	12,10	11,40	10,00	8,40	6,70	5,00
max.	10,13	10,86	11,84	12,84	13,68	14,09	13,87	13,14	12,16	11,16	10,32	9,91
	50%	54%	59%	65%	76%	84%	87%	87%	82%	75%	65%	50%
Radiation (MJ/m²day)	11,03	12,96	17,70	22,40	26,80	30,70	32,70	27,29	24,20	19,25	13,90	10,54

Temperature °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extreme Max	24,0	25,1	26,3	33,0	39,0	38,3	39,0	41,5	39,0	34,6	28,0	24,8
Mean Max	10,1	11,5	15,0	20,2	25,2	28,1	29,5	29,6	28,3	25,1	18,2	12,4
Mean	6,4	7,4	10,2	14,6	18,9	21,9	23,6	23,6	22,2	19,0	13,1	8,4
Mean Min	2,7	3,2	5,4	8,9	12,5	15,7	17,7	17,6	16,0	12,8	8,0	4,3
Extreme Min	-8,3	-4,5	-6,5	-1,5	1,4	4,5	8,5	8,8	4,5	3,4	-2,0	-4,8

Precipitation mm/month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	346	285	234	268	54	0	0	0	5	92	204	305
Average	110	98	87	25	5	0	0	0	0	10	48	90
Minimum	74	64	58	18	3	0	0	0	0	8	31	58

Humidity %

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Max	79	74	67	58	51	50	52	54	56	56	64	75
Average	74	69	62	53	46	45	47	49	51	51	59	70
Mean Min	69	64	57	48	41	40	42	44	46	46	54	65

Wind Direction and speed: m/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direction	SW	SW	SW	S	S	S	S	S	S	S	SW	SW
Speed	2,6	2,6	2,5	2,5	3,0	2,0	2,2	2,0	1,9	2,2	2,2	2,4

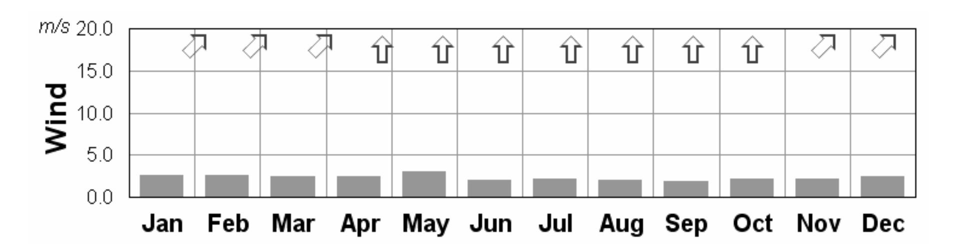


Figure 2: Wind Data, University of Jordan Station, Amman (Generated by Excel Template) (Jordanian Metrological Department, 2003)

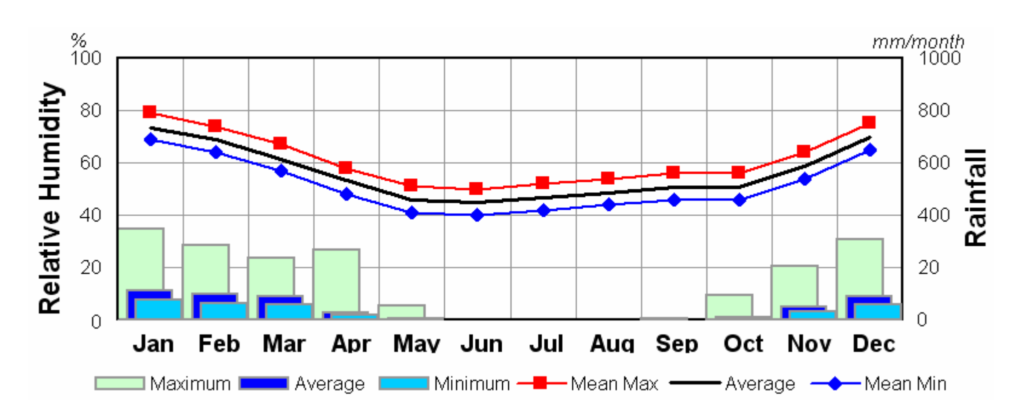


Figure 3: Humidity and Rainfall Data, University of Jordan Station, Amman (Generated by Excel Template) (Jordanian Metrological Department, 2003)

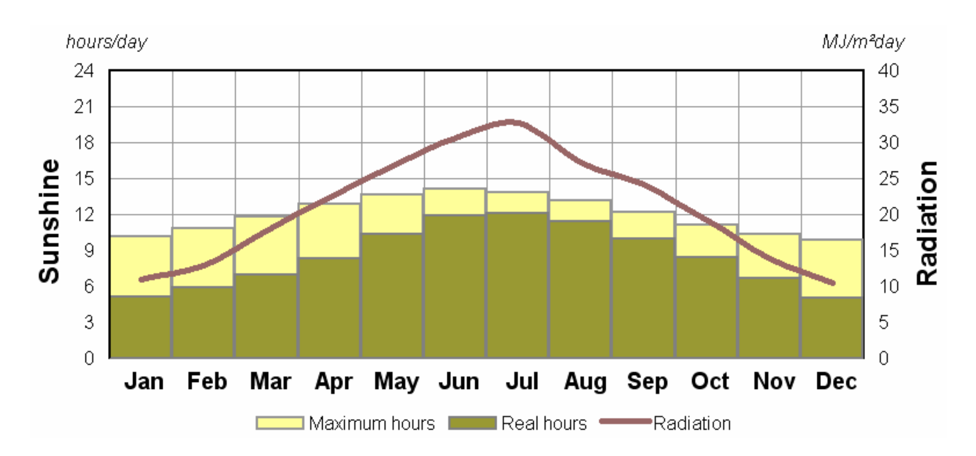


Figure 4: Sunshine and Radiation Data, University of Jordan Station, Amman (Generated by Excel Template) (Jordanian Metrological Department, 2003)

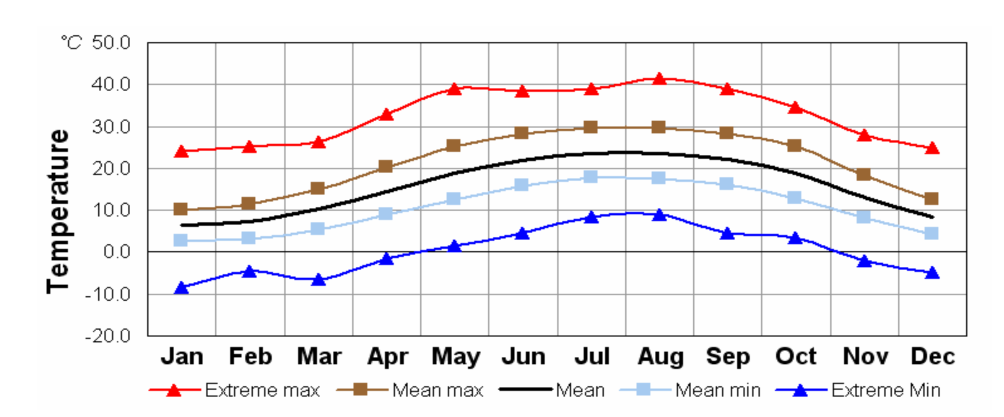


Figure 5: Temperature Data, University of Jordan Station, Amman (Generated by Excel Template) (Jordanian Metrological Department, 2003)

Table 3: Mahoney Table, University of Jordan Station, Amman (Generated by Excel Template) (Jordanian Metrological Department, 2003)

Amman, University of Jordan
Latitude 35°N

Indicator totals from data sheet					
H1	H2	H3	A1	A2	A3
0	0	0	8	0	6

General recommendations

H1	H2	H3	A1	A2	A3		
							Layout
			0–10			X	Orientation north and south (long axis east–west)
			11–12		5–12		
					0–4		Compact courtyard planning
							Spacing
11–12							Open spacing for breeze penetration
2–10							As above, but protection from hot and cold wind
0–1						X	Compact layout of estates
							Air movement
3–12							Rooms single banked, permanent provision for air movement
1–2			0–5				
			6–12				Rooms double banked, temporary provision for air movement
0	2–12						
	0–1					X	No air movement requirement
							Openings
			0–1		0		Large openings, 40–80%
			11–12		0–1		Very small openings, 10–20%
Any other conditions						X	Medium openings, 20–40%
							Walls
			0–2				Light walls, short time-lag
			3–12			X	Heavy external and internal walls
							Roofs
			0–5				Light, insulated roofs
			6–12			X	Heavy roofs, over 8h time-lag
							Size of opening
			0–1		0		Large openings, 40–80%
					1–12		Medium openings, 25–40%
			2–5				
			6–10			X	Small openings, 15–25%
			11–12		0–3		Very small openings, 10–20%
					4–12		Medium openings, 25–40%
							Position of openings
3–12							In north and south walls at body height on windward side
1–2			0–5				
			6–12			X	As above, openings also in internal walls
0	2–12						
							Protection of openings
					0–2		Exclude direct sunlight
		2–12					Provide protection from rain
							Walls and floors
			0–2				Light, low thermal capacity
			3–12			X	Heavy, over 8h time-lag
							Roofs
10–12			0–2				Light, reflective surface, cavity
			3–12				Light, well insulated
0–9			0–5				
			6–12			X	Heavy, over 8h time-lag
							External features
				1–12			Space for outdoor sleeping
		1–12					Adequate rainwater drainage

On the other hand, Givoni chart generated by the template, (see figure 6) is used to define human thermal comfort needs inside a building in the location at which the climate data was collected. The chart indicates the months in which thermal comfort is achieved inside a building without any kind of active (or mechanical) heating or cooling, along with the temperature, vapor pressure and relative humidity associated with it. It also indicates comfort methods in order to reach this comfort zone, by either passive or active measures, such as air movement, night ventilation, additional heating, air conditioning and more.

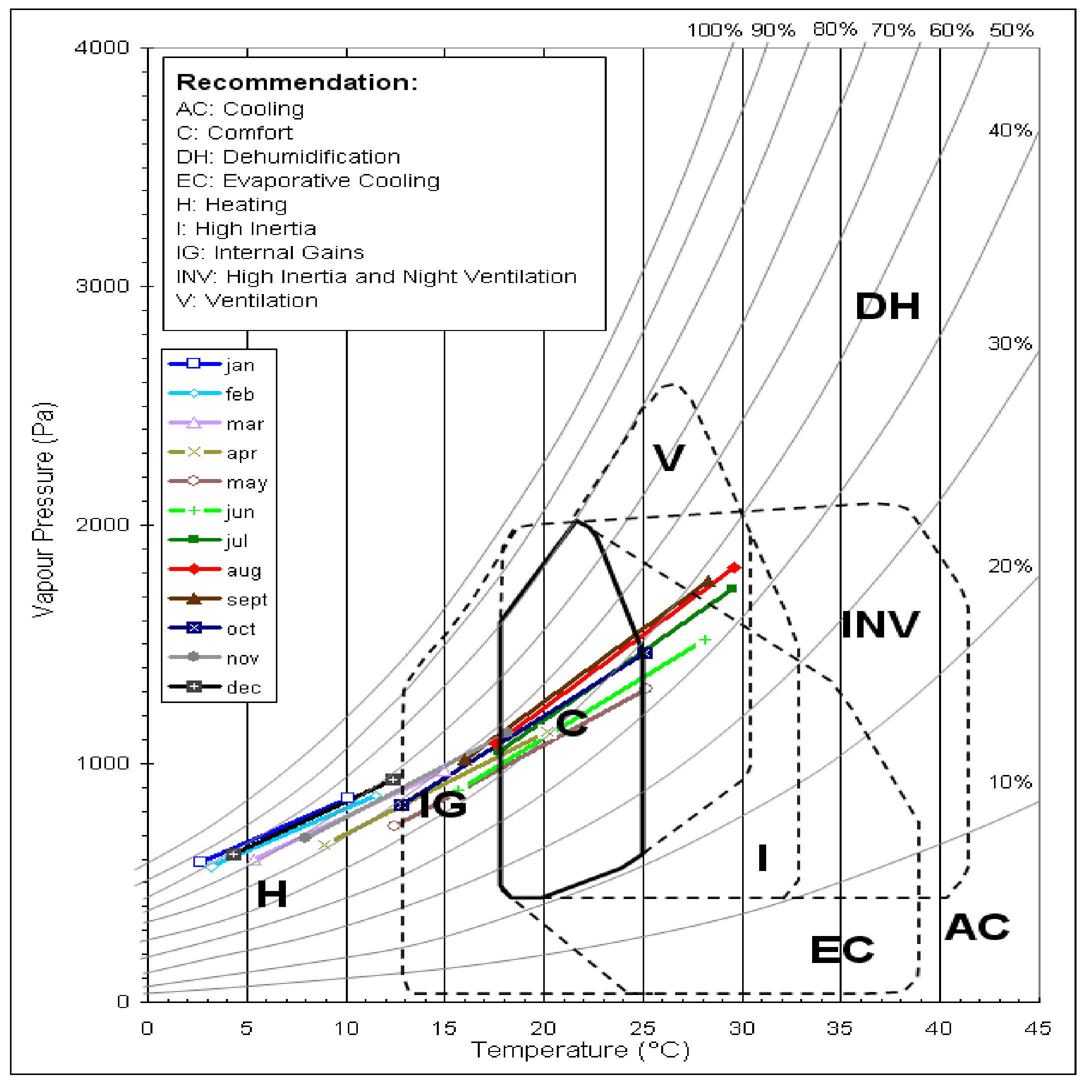


Figure 6: Givoni Chart, University of Jordan Station, Amman (Generated by Excel Template) (Jordanian Metrological Department, 2003)

2-4-3 Construction sector:

Table (4) represents number of licenses, licensed area and the cost for new buildings and the extensions (residential and non- residential) built in Jordan, between the years 2006 and 2008.

Table 4: Building statistics in Jordan. (JEA, 2009)

Indicator	2006	2007	2008
Number of buildings licenses	**13909**	**11174**	**9542**
Residential	12623	10191	8732
Non-residential	*1286*	*983*	*810*
Total area of buildings (by 1000 m^2)	**8378**	**6658**	**6400**
Residential	6696	5210	5148
Non-residential	*1682*	*1448*	*1252*
Estimated cost (million JD)	**963**	**751**	**991**
Residential	779	588	793
Non-residential	*184*	*162*	*198*

Although the numbers of licenses and total area of the non-residential (commercial) buildings are decreasing slightly, the total estimated cost is rising significantly. This is due to considerable factors such as cost of materials, technological requirements, high HVAC requirements and demand.

2-4-4 Energy Sources:

a) Oil Source:

It is now universally conceded that fossil fuel resources in the world are finite and it is only a matter of time before reserves will essentially be depleted. On the other hand, Jordan depends almost exclusively on imported fuel which totaled to 5.678 million Tons Oil Equivalent (TOE) in 2005 as stated by the Ministry of Energy and Mineral Resources, and the concern over the future availability of fuels has caused an increased awareness of the need to conserve energy specially in the residential sector.

b) Renewable sources:

Jordan is blessed with an abundance of solar energy, with high average daily solar radiation of 5 to 7 kWh/m^2, which is one of the highest in the world. The average sunshine duration is more than 300 days per year. National Energy Research Centre (NERC) is conducting a long-term project for collecting and evaluating solar radiation to have new solar data. For this purpose, 14 measurement stations were installed around the country.

However, solar energy is not widely used, except for solar water-heaters, which are used for heating of domestic water. In addition to the economic benefit, the use of solar radiation instead of conventional fuels reduces the level of air pollutants; including greenhouse gas emissions. In the year 2002, the total area of installed solar collectors in Jordan was more than 1,135,000 m^2. (UNFCCC) 2009.

Renewables seem to be a promising option in Jordan, for that the academic and professional establishments start to think about sources of renewable energy and to make the way as smooth as possible to implement the renewable solutions.

2-4-5 Energy demand:

Due to economic growth and increasing population, energy demand is expected to rise by at least 50 percent over the next 20 years. The provision of reliable energy supply at reasonable cost is thus a crucial element of economic reform and sustainable development. Although the demand will be increasing, however, the dependency on conventional oil sources is expected to decrease. (UNFCCC) 2009

Jordan can decide to boost its economy by actively participating in clean technologies, more specifically in clean energy, which includes renewable energy, energy efficiency, environmentally friendly production, conservation and pollution mitigation. (Ottermans and Degrees, 2010)

From table (5), we find that energy consumption, specifically electricity consumption, in commercial and office buildings are relatively high, and increasing annually, this calls for desperate measures regarding regulating energy consumption and environmental and climatic design requirements for this type of buildings.

2-4-6 Commercial Sector:

a) General:

For Greater Amman Municipality Zone, the commercial areas are intended for commercial, residential, public purposes. The zones of commercial buildings are divided into central and ordinary commercial sectors. There are also local commercial sectors within the housing sectors. Buildings in the commercial sectors are subjected to the provisions indicated in table (6).

b) Energy consumption:

In order to compromise these expenses, important measures must be taken for the optimization in the use of the construction materials in ways to ensure lower operational costs for the building, especially concerning energy.

The national statistics show that commercial uses in the constructional sector uses over 4.5 percent of electricity, equivalent to 804000 TOE annually, and there is an estimation of a potential in saving of more than 20 percent of the overall energy consumption in this sector, equivalent to 160 800 TOE, when adopting rationalization in energy consumption programs. (GTZ, 2007)

Table 5: Purpose of Electricity consumption (Giga Watt/ hour) in Jordan. (Statistics department, 2009)

Indicator	2005	2006	2007	2008
Industrial	2715	2757	2917	3128
Household	2996	3435	4017	4459
Commercial	*1274*	*1516*	*1758*	*1925*
Water pumping	1353	1396	1592	1713
Street illumination	288	261	269	284
Others	220	228	-	-
Total	**8786**	**9593**	**10553**	**11509**

Table 6: Commercial Sector provisions. (Greater Amman Municipality, 2005)

Commercial Sector	Max. plot coverage (%)	Plot size (m^2)	Max. FAR	Max. Building height (m)	Building depth (m)	Setback (m)		
						Front	Back	Sides
Central	85	<200	6	72		-	*	*
		>200	10			-		
Ordinary	70	<600	6		<18	-	4	-
		>600	8.5	**	>18	-	4	4

* *The setback could be either backward or sideways provided that any distance will be at least 2.5 m from the plot border. The building may have a courtyard of minimum 15 percent of the plot size.*

** *The maximum building height should be less or equal to the street width along with the front setback, if any. However, maximum is 72 m.*

(II)- 5

LAWS AND POLICIES

2-5-1 General:

Energy rationalization and audit exercises were developed and monitored by Governmental authorities, universities and research centers through the past two decades with a definitive positive energy reduction and beneficiation. (Khalil, 2010).

Higher energy use and comfort creates a demand for efficient and reliable supply, and environmental concerns lead to the use of cleaner energy sources. Therefore, a conscious energy supply policy and relevant guidelines for housing design, will have great impact on social well-being and economic development. . (Rosenlund et.al. 2004)

Governmental organizations were established earlier to be responsible for energy planning and efficient utilization, information dissemination and capacity building as well as devising the necessary codes and standards. The development of the relevant codes for Residential and Commercial Energy Efficiency in Building is underway through the governmental bodies responsible for the research and development in the building technology sector is the umbrella under which the National and Unified Arab Codes are developed and issued. (Khalil, 2010).

2-5-2 International Experience:

a) Energy Performance of Buildings Directive (EPBD):

The Energy Performance of Buildings Directive (EPBD) lays down requirements as regards:

- The general framework for a methodology of calculation of the integrated energy performance of buildings;
- The application of minimum requirements on the energy performance of new buildings.

- The application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation;
- Energy performance certification of buildings;
- Regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.

The government has to put a timeframe and a strategy for such requirements and implementation methods in Jordan. The EPBD has stated that the methodology of defining the energy performance of a building must be based on the following specifications:

- Thermal characteristics of the building (shell and internal partitions, etc.) these characteristics may also include air tightness;
- Heating installation and hot water supply, including their insulation characteristics.
- Air-conditioning installation;
- Ventilation;
- Built-in lighting installation (mainly the non-residential sector);
- Position and orientation of buildings, including their insulation characteristics;
- Passive solar systems and solar protection;
- Natural ventilation;
- Indoor climatic conditions, including the designed indoor climate.
- Active solar systems and other heating and electricity systems based on renewable energy sources;
- Natural lighting.

b) United States Green Building Council (USGBC) Green building rating system:

The United States of America (USA) has a program called Leadership in Energy and Environmental Design (LEED) for green building rating and assessment. LEED promotes expertise in green building through a comprehensive system offering project certification, professional accreditation, training and practical resources. (USGBC, 2010)

Leadership in energy and environmental design (LEED) rating system has been proposed as a program that recognizes performances in buildings in five key areas of human health and environment:

- Sustainable site development
- Water savings
- Energy efficiency
- Materials selection
- Indoor environmental quality

c) British Environmental Assessment Method (BREEAM)

BREEAM (BRE Environmental Assessment Method) is the leading and most widely used environmental assessment method for buildings. It sets the standard for best practice in sustainable design and has become the de facto measure used to describe a building's environmental performance. (BREEAM, 2010)

BREEAM provides clients, developers, designers and others with:

- Market recognition for low environmental impact buildings.
- Assurance that best environmental practice is incorporated into a building.
- Inspiration to find innovative solutions that minimize the environmental impact.
- A benchmark that is higher than regulation.

- A tool to help reduce running costs, improve working and living environments.
- A standard that demonstrates progress towards corporate and organizational environmental objectives.

BREEAM addresses wide-ranging environmental and sustainability issues and enables developers and designers to prove the environmental credentials of their buildings to planners and clients. It uses a straightforward scoring system that is transparent, easy to understand and supported by evidence-based research. It also has a positive influence on the design, construction and management of buildings. In addition, it sets and maintains a robust technical standard with rigorous quality assurance and certification.

d) Qatar Sustainability Assessment System (QSAS)

The primary objective of Qatar Sustainability Assessment System (QSAS) is to create a sustainable built environment that minimizes ecological impact while addressing the specific regional needs and environment of Qatar. The development of the rating system has taken advantage of a review of combined best practices employed by a mix of established rating systems. This review has been performed while considering the needs that are specific to the region's environment, culture, economy and policies. (QSAS, 2010)

To derive a rating system that responds to local priorities, it is important to translate them into a set of value statements. Each statement expresses a particular need of society, such as the need to create a livable urban fabric, the need to conserve water, and the need to safeguard against long term health risks of the population. Studying the local situation in Qatar has led to the formulation of value statements that are at the core of the rating system development.

Each value statement constitutes a major category in QSAS, subsequently populated by the specific criteria with associated measurements that together quantify the category as a whole. The response to local needs has been carried out in three major interrelated steps:

- Representing the local culture, circumstances and ecosystem by a set of discrete value statements
- Populating each category with criteria for which a (outcome based) measurement method is implemented to rate a category as a whole; and the weighting of each category by local stakeholders to aggregate an outcome over all categories
- Taking into account the local circumstances, practices and customs at each step.

Measurements for the rating system are designed to be performance-based and quantifiable, wherever possible. The combination of international best practices and regional needs and goals has led to a comprehensive green building rating system customized to the unique conditions and requirements of Barwa/Diar and the State of Qatar.

Qatar Sustainability Assessment System was developed by BARWA Real Estate Company and Qatari Diar Real Estate Investment Company in partnership with the TC Chan Center for Building Simulation and Energy Studies at the University of Pennsylvania. QSAS is administered by the Barwa and Qatari Diar Research Institute.

e) ESTIDAMA

The Abu Dhabi Urban Planning Council (UPC) is recognized internationally for large-scale sustainable urban planning and for rapid growth. Plan Abu Dhabi 2030 urban master plan addresses sustainability as a core principle.

ESTIDAMA, which is the Arabic word for sustainability, is an initiative developed and promoted by the UPC. ESTIDAMA is the intellectual legacy of the late Sheikh Zayed bin Sultan Al Nahyan and a manifestation of visionary governance promoting thoughtful and responsible development while creating a balanced society on four equal pillars of sustainability: environmental, economic, social, and cultural. The goal of ESTIDAMA is to preserve and enrich Abu Dhabi's physical and cultural identity, while creating an always improving quality of life for its residents. (ESTIDAMA, 2010)

The early foundations and aspirations of ESTIDAMA are incorporated into Plan 2030 and other UPC policies such as the Development Code. ESTIDAMA began two years ago and is the first program of its kind that is tailored to the Middle East region. In the immediate term, ESTIDAMA is focused on the rapidly changing built environment. It is in this area that the UPC is making significant strides to influence projects under design, development or construction within the Emirate of Abu Dhabi. An essential tool to advance ESTIDAMA is the Pearl Rating System.

The Pearl Rating System for ESTIDAMA is a framework for sustainable design, construction and operation of communities, buildings and villas. The Pearl Rating System is unique in the world and is specifically tailored to the hot climate and arid environment of Abu Dhabi. The extreme summer temperatures of Abu Dhabi reach 48°C and humidity levels can be near 100 percent. Air conditioning consumes large amounts of electrical energy. . (ESTIDAMA, 2010)

The Pearl Rating System is part of the government wide collaborative initiative to improve the lives of all citizens living in Abu Dhabi Emirate, by supporting the social and cultural traditions and values of Abu Dhabi. It reinforces what this unique place has been in the past and hopes to be long into the future.

All new projects must achieve a minimum 1 Pearl rating to receive approval from the planning and permitting authorities. Government funded buildings must achieve a minimum 2 Pearl rating.

Abu Dhabi's Plan 2030 establishes a clear vision for sustainability as the foundation of any new development occurring in the Emirate and capital city of Abu Dhabi. This commitment is a reflection of the values and ideals of the Arab nations. The tenets of sustainable living in the Middle East is the guiding force behind ESTIDAMA. More than just a sustainability program, ESTIDAMA is the symbol of an inspired vision for governance and community development.

It promotes a new mindset for building a forward thinking global capital. To establish a distinctive overarching framework for measuring sustainability performance beyond the usual planning and construction phases, UPC has worked with the team guiding ESTIDAMA to assure that sustainability is continually addressed through four pre-defined angles: environmental, economic, social and cultural.

The purpose of ESTIDAMA is to create a new sustainability framework that will direct our current course while allowing adaptation as new understanding evolves. By promoting a new sense of responsibility with ESTIDAMA, UPC is going beyond other sustainable development initiatives around the world, by creating new tools, resources and procedures crucial to the 2030 vision. (ESTIDAMA, 2011)

2-5-3 Local Experience:

a) Background:

According to the national Jordanian agenda prepared in 2005, it is purposed for the energy consumption to be minimized and rationalized in all means available in all sectors in concurrence with accredited regulations and specifications.

Based on the same agenda, it is expected that the initial consumed energy will reach for approximately 16 773 TOE in 2020. (GTZ, 2007)

Jordan has launched the first campaign in the world that relates all groups and classes of the society, and the third in the world on the footsteps of the effort of Ove Arup original campaign, Drivers of change, in 2009.

The output of the campaign will consist of a separate unique version of drivers of change based on Jordanian parameters and contributions. One of Jordan's efforts is to cope and harvest change with promotion of green buildings, and especially in the field of energy efficiency. (Arup, 2009)

The Government of Jordan has adopted a national strategy for improving energy efficiency in all sectors in the Kingdom, where several measures and actions are needed to be implemented throughout this strategy. (UNFCCC) 2009

The main goals of this strategy are:

(1) to reduce energy consumption without negatively affecting the size of production or the standard of living; which will lead to a lower national imported oil bill and also reduce the national emissions of Green House Gases (GHGs).

(2) to improve the standard of living

(3) to achieve balance between imports and exports

(4) to reduce production cost and enhance competitiveness of the local industries and other sectors

(5) to reduce investment in the equipments used for production, conversion, transmission and distribution of electrical energy.

b) Building-Energy regulations in Jordan

1) General:

The Royal Energy Committee was formed to undertake the following tasks: (UNFCCC) 2009

- review and modernize the national energy strategy
- reconsider restructuring of the energy sector in Jordan and to recommend ways to provide the needed energy, particularly the alternative and renewable energy resources
- draw a work program with clear mechanism and specified cost and time frame.

Consequently, the committee initiated the development of the following codes at the end of 2007;

- Updating the existing Thermal Insulation code.
- Drafting a new Energy Efficient Buildings code.
- Drafting a new Gas Piping in Buildings.
- Drafting a new Solar Energy Code.
- Drafting a new Green Building Guideline for Jordan.

2) Building Codes and Domain of practice:

Appendix B in this research shows the phases of preparations of general codes of practice, and elaborations on a number of related building energy consumption codes.

The following pyramid shows the relation of domain of the codes, mandatory and voluntary requirements: (Author, 2010)

Green building Guideline Voluntary for all new buildings
Energy Efficient Building Code Mandatory for all new buildings, and Voluntary for new residential buildings that don't exceed 5 floors in height
Solar Energy Code Mandatory for all new buildings that consists of 5 floors or less
Thermal Insulation Code Mandatory for all new buildings

3) Green Building rating system in Jordan:

The establishment of such rating system here in Jordan was suggested, which has to be either obligatory by the government or has to give incentives according the efficiency of the performance of the building, since green buildings have a profound impact on our natural environment, economy, health and productivity.

The final draft of the new Green Building Guideline and Rating System of Jordan was established and approved by the Jordan National building council, in November 2010.

The green building guideline and rating system for Jordan is Referenced to Jordan's Related Building Codes (as compulsory requirements), and International green rating systems such as (LEED) rating system from the United States, (BREEAM) assessment tool from the United Kingdom, (ESTIDAMA) from the United Arab Emarites, Dubai green building rating system, QSAS from the State of Qatar, and many more. See Appendix B.

(II)- 6

PASSIVE DESIGN

2-6-1 Background:

The degradation of the natural environment and the exhaustion of depleted resources reach unprecedented levels, which pose critical challenges to planners and policy makers to find the solutions and substitutions to the traditional energy sources. Though planners set the subjective goals for sustainable development, scientists are who set the objective goals.

Buildings are our third skin. To survive we need shelter from the elements using three skins. The first is provided by our own skin, the second by a layer of clothes and the third is the building. In some climates it is only with all three skins that we can provide sufficient shelter to survive, in others the first skin in enough. The more extreme the climate, the more we have to rely on the building to protect us from the elements, just as we take off and put on clothes as the weather and the climate changes so we can alter our buildings to adapt to changes in climate. (Roaf, et al., 2004)

Energy efficiency is not a new criterion of design. The context of building has always been defined by climatic and material limitation. Even when these are severe, they have not prevented building designers from evolving solutions of great craft and elegance. (Watson, 1979)

2-6-2 Philosophy:

Architects have in their hands the talent and control to reduce energy consumption. It does not only depend on external technology such as solar power, wind power and photovoltaic power, but the building itself can solve a series of problems. If that approach is translated into design, then more than 50 percent of the problems can be solved by the design philosophy. (Lerum, 2008)

The design of the building envelope is generally the responsibility of an architect, although a contractor, an engineer, or some other person may do it. The designer is responsible for making sure that the building envelope complies with the Standards. Likewise, the building official is responsible for making sure that the building envelope is designed and built in conformance with local standards. (California, 2005).

2-6-3 Objective:

The first aim of passive design is to maximize passive systems to reduce the reliance on active systems which use energy. (Smith, 2006)

The primary objective in the design of a passive solar building is to prevent overheating while at the same time achieving high savings in energy consumption. In direct gain systems the solar energy transmitted through south-facing windows is stored directly in the space where it is to be used, that is, in storage mass distributed in the room interior. In indirect systems the energy is stored in specially built storage elements such as a rocked or a Trombe wall (a collector– storage wall). (Athienitis and Santamouris, 2002).

2-6-4 The design process:

a) General:

Architects have a crucial role to play in designing buildings to minimize energy use for active climatization and lighting. A good approach is to take advantage of natural means such as solar radiation, and use the building as a collector, storage and transfer mechanism (Der-Paterssian and Johansson, 2000)

Since the sun drives every aspect of the climate it is logical to describe the techniques adopted in building to take advantage of this fact as 'solar design'. The most basic response to take full advantage of solar gain without any intermediate operations.

Buildings should passively adapt to the climate as much as possible; that is, the building should provide a reasonable indoor climate with little or no energy input. The best use should be made of the thermal properties of materials.

b) Methodology:

There is no ultimate solution for a sustainable or low-energy design. Each case is unique; each site has its own conditions and each climate sets its limits. Further, esthetic, cultural, functional, technical and economic aspects have important influence on building design. Hence, recommendations on climatic design have to be very general. Nevertheless, we will attempt to set an order of priority or checklist to reduce energy use in buildings. (Rosenlund et.al. 2004)

It is clear that climatic design has to be considered at an early design stage, and be integrated in the design process to be efficient, since much of it deals with choice of building materials and form of building, openings, orientation, etc.

Each building is different, thus, it needs a different design approach where it depends on the function, climate, orientation and transparency desires.

In the early stages of design, the building design team has to choose from a wide variety of design options, which can become a very difficult choice, because of the involvement of many subjective factors, in addition to the overall optimization of the indoor environment, which further compounds the problem. Therefore, traditional passive designs are often suggested as the “safe” traditional solution in the final stage, leading to false decisions and design.

c) Building Envelope

The basic idea of passive design is to allow daylight, heat and airflow only when they are most beneficial, and to exclude them when they are not. The correct orientation of the building, appropriate amounts of fenestration and shading, an efficient envelope, maximum use of daylighting and the appropriate level of thermal mass are considered in passive design, as well as the use of renewable resources. In addition, it is necessary to appreciate the degree to which solar access is available, so that solar heat gain can be determined.

Access to solar radiation is determined by a number of conditions and factors, listed in the following: (Smith, 2006).

- The sun's relative position to the principal facades of the building (solar altitude and azimuth);
- Site orientations and slope;
- Existing obstruction on the site;
- Potential for overshadowing from obstructions outside the site boundary;

For the development of the project itself, the following factors need to be considered: (Smith, 2006).

- Grouping and orientation of buildings;
- Road layout and services distribution;
- Proposed glazing types areas, and façade design;
- Nature of internal spaces into which solar radiation penetrates.

The simplest type of passive system is the direct gain approach through windows, usually double glass, ideally facing south. To help store the heat, such a building design should include considerable thermal mass, such as poured concrete floors or massive masonry construction in the walls or ceiling with insulation on the outside. In a sense, the building becomes a live-in solar collector. The south orientation offers seasonal control automatically, since the south face is exposed to a maximum amount of solar energy in the cold winter months when sun angles are low, and a minimum in the summer when sun angles are high. (Watson, 1979)

d) Parameters and principles:

A key aspect of passive solar design is choice of the following design parameters: (Athienitis and Santamouris, 2002)

- Fenestration area, orientation and type.
- Shading device type, locations and areas.
- Effective thermal storage (insulated from the exterior environment) amount and type (sensible – such as concrete in the building envelope with exterior insulation, or latent – such as phase-change materials).

The above basic design parameters are interlinked and dependent on each other. The ultimate design objective is minimization of energy costs (heating, cooling, electricity) while maintaining good interior thermal comfort.

Good passive design for thermal comfort is based on the following six major principles: (Smith, 2006)

- Orientation of frequently used areas towards the Equator (north in the southern hemisphere, south in the northern hemisphere), to allow maximum sunshine when it is needed for warmth, and to more easily exclude the sun's heat when it is not.

- Glazing used to trap the sun's warmth inside a space when it is needed, with adequate shading and protection of the building from unwanted heat gain or heat loss.
- Thermal mass to store the heat from the sun when required, and provide a heat sink when the need is for cooling.
- Insulation to reduce unwanted heat losses or heat gains through the roof, walls, doors, windows and floors.
- Ventilation to provide fresh air and capture cooling breezes.
- Zoning of internal spaces to allow different thermal requirements to be compartmentalized when required.

2-6-5 Passive design in Jordan

The climate of Jordan shows great potential of passive heating using solar energy. With an adequate design, it should be possible to achieve so called zero energy buildings, buildings that require virtually no energy for heating and cooling. It is common to use thermal insulation in Jordan, however, it is often badly applied resulting in thermal bridges and heat is often lost through gaps in the thermal insulation layer. There is a need for more adequate training for the construction workers applying thermal insulation and developing better equipment and procedures. (MPWH, 2010)

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THE BUILDING ENVELOPE

2-7-1 General:

The building envelope is responsible for the most significant loads that affect heating and cooling energy use. The principal components of heating loads are building envelope infiltration as well as conduction losses through building envelope components – including walls, roofs, floors, slabs, windows and doors. Solar gains through the windows dominate cooling loads in conditioned buildings, but loads through the ceiling/roof and walls are also significant. (California, 2005)

Much more energy would be possible to save in the colder zones by, e g, increasing envelope insulation. This would however require a more conscious life-cycle cost perspective, where investments in building construction and services are balanced against the running costs. Pay-back periods are likely to shrink with increasing energy prices. Some improvements in building design are at low or even no cost, and may permit an indoor comfort level with small or even no investment in active systems. (Rosenlund et.al. 2004)

In modern architecture, the reduction in thickness of the exterior walls and the increased use of glazing in the facades has made the design of good daylighting more difficult. Various kinds of shading devices might be necessary not only to avoid overheating but also to control the interior lighting and avoid glare from the windows. (Kuller, 2004)

Loads from the building envelope, especially windows and skylights, are among the most significant loads that affect heating and cooling energy use. (California, 2005).

The principal components of heating loads are infiltration through building envelope and conduction losses through building components, including walls, roofs, floors, slabs, windows and doors.

2-7-2 Orientation

a) Background:

The placement and orientation of buildings is crucial to make best use of solar energy and other natural characteristics, such as topography and trees, to control wind and shade. (Der-Paterssian and Johansson, 2000)

The movement of Earth around the sun is the most important natural element to take into account when designing an energy efficient house. Since the sun is the main source of heat, a major principle of energy efficient design is to allow that heat into the house in the winter, and exclude it in the summer. Fortunately, this is easily achievable since the angle of the sun changes from season to season.

In areas where comfort is acquired mainly by air movement, such as hot-humid areas, it is important to orient the building according to prevailing winds. (Rosenlund, 2000)

In regions where ambient temperature has greater influence on comfort than ventilation, orientation with respect to the sun is important. A North-South orientation of the main façade is preferable, since the summer sun penetrates facades and openings only marginally in these directions, while in winter when the path of the sun is lower, there is possibility of solar access. Correctly placed windows and sun spaces can take advantage of the sun for winter heating but must be protected during hot seasons.

b) Whole building orientation

During the summer months, the sun rises in the North-East and ascends slightly southwards until it becomes almost perpendicular to the earth's surface at noon, after which it descends again towards the North-West. The main heat gain of a house during the summer comes from the roof, as well as from the east and west facades. Therefore, it is important to shade and obscure the roof and any east and west facing windows and walls. During the winter months, the path of the sun is much shorter -it rises in the South-East, and remains at a low angle as it moves towards the south before setting again in the South-West. As such, the main heat gain during the winter comes from the south façade of the house. South facing windows and walls, therefore receive maximum warmth during the winter. (Ouhrani, 1999)

When choosing a site criteria is applicable, ensuring that no obstructions such as buildings or trees in front of the south façade, is most important. The distance between the south façade and obstacles should be at least 1.5 times the height of the obstacle.

An orientation perpendicular to true south is best. If there is a deviation, it should ideally not be more than 15 degrees. The longer side towards the south will allow more sun to enter the house during winter. However the ratio should not exceed 1.5 because the more longitudinal the building, the greater the surface area subjected to external weather - the sun in the summer or wind in the winter. The best ratio for a building would be 1:1.2 in all areas of Jordan. (Lund and RSS, 2009)

c) Windows orientation

1) General:

Windows should be oriented with respect to the sun path so that comfortable internal daylight levels are obtained, without excessive solar heat gain, glare or contrast. (Athienitis and Santamouris, 2002).

In concern to wind direction orientation, windows should take into consideration ventilation and air movement requirements when oriented and designed. This issue will not be covered in this study because of the dependence of case study buildings on active heating and cooling systems not natural ventilation.

2) South-facing windows:

South facing windows have the highest levels of solar heat gain in winter when the solar radiation angles are low. However, in the summer season, the illumination is variable throughout the day. South facing windows are preferable in Cold/ or temperate climates where solar gain is most needed.

The best size for South-facing windows largely depends on the location of the building. In cooler, hilly areas, larger window sizes are more suitable, provided they are double glazed and air-tight. In warmer areas, smaller window sizes are better, and shading overhangs become important.

For example in Amman, 20-30 percent of the elevation area should be glazed. This can go up to 40 percent if the windows are double glazed and shaded. In Aqaba, the smaller the area of window openings, the better. (CSBE, 2009)

3) East and west-facing windows:

East and West-facing windows have medium luminous levels, high energy gain in summer, low in winter. In addition, east orientation has high illumination in the morning, west is high in the afternoon. East- and west- facing windows can be considered comparable, although their maximum light levels occur at different times of the day, so any control systems (in terms of solar shading or heat gain) should be movable.

The area of these windows should be kept to a minimum. Full vertical screening (external shutters) or deciduous trees are the only shading devices that can block low sun in the early and late summer. However, western windows are also important for cross ventilation in some Jordanian cities (e.g. Amman) because of the direction of the prevailing summer breeze. Once again, ventilation will not be covered in this study.

4) North-facing windows:

North facing windows have low levels of illumination throughout the year. Low Solar heat gain is expected from them due to the lack of Solar transmittance of the north orientation. This is most beneficial in hot climates where solar heat gain is not prepared, thus, orientation of major activity zones to the North.

In addition, they lose considerable heat during winter, but only need minimal vertical shading and internal blinds to block out the summer sun. The use of double-glazed windows for northern windows is most important as it minimizes heat loss during the winter. (CSBE, 2009)

Fixed systems are more suitable for south- and north-facing windows, next to which activities requiring higher light levels should preferably be located.

2-7-3 Opaque Parameters (the building envelope without fenestration)

a) Background:

The choice of building materials is one of the most obvious factors affecting energy use in buildings. All building materials possess both thermal resistance and thermal capacity (inertia) in different proportions. These properties are more or less the opposite of each other, and there are three factors influencing them. Density, the lighter the material the more insulating, the heavier the more heat storing, conductivity is the ability to conduct heat, insulating materials have low conductivity, and specific heat capacity indicates how much energy can be stored in the material.

b) Thermal mass:

The thermal mass of a building depends on which materials are used in the building envelope in regards to their physical and thermal properties. Thermal mass causes the building to delay its response to heat variation in comparison between indoors and outdoors. This is called the heat or thermal lag effect.

We have long been under the impression that some insulation in buildings is good and that more is better. This generally holds true for residential buildings, but is not necessarily true for commercial, industrial, and institutional buildings. (Watson, 1979)

A residential building is generally a “light” structure, which may be defined as one in which the heating and cooling requirements are roughly proportional to the difference between indoor and outdoor temperature. Other examples of a thermally light building would include structures that are heated only with little or no internal gains, such as warehouses.

A thermally "heavy" structure is one in which the heating and cooling requirements are not directly proportional to the difference between indoor and outdoor temperature due to the presence of cooling and internal or solar heat gains. Examples of this type of thermally heavy structure include most any commercial, industrial or institutional building. (Lerum, 2008)

This is most important in order to demonstrate a technique for determining the optimum U-values for walls, roofs, etc., in thermally heavy structures. It is recognized that the energy requirements for these structures vary so widely that there can be no generalizations made with regard to the use of insulation.

This is quite contrary to the generalizations regarding insulation used in the design of light thermal structures, which say more insulation will reduce energy consumption. Other factors to be considered in any analysis are the equipment capacity and thermal comfort associated with changes in U-value. The higher the U-value, the greater equipment capacity and size.

In temperate or cold climates, the building design should allow passive heating from solar radiation during the cold season. To limit heat loses the building envelope should have sufficient thermal insulation and windows and doors should be sealed. (Paterssian et.al 2000)

Table (7) shows the properties of thermal mass of some of the building materials other than the insulation materials.

c) External Walls:

Basic decisions about external walls should be taken at a relatively early stage in the design process, and they include the following: (Athienitis and Santamouris, 2002)

Table 7: Properties of thermal mass and other building materials (ASHRAE, CIBSE)

Material	**Mass density (kg/m³)**	**Thermal conductivity (w/mk)**	**Specific heat (J/kg K)**
Heavyweight concrete	2243	1.73	840
Clay tile	1121	0.57	840
Gypsum	1602	0.73	840
Gas-entraind concrete	400	0.14	1000
Water	1000	0.58	4200
Plasterboard	840	0.46	950
Expanded polystyrene	25	0.035	1400
Softwood	630	0.13	1360
Hardwood	630	0.15	1250
Plywood	530	0.14	1214
Shipboard	800	0.15	1286
Common brick (full)	1922	0.727	840
Granite	2600	2.50	300
Limestone	2180	1.59	720
Sandstone	2000	1.30	712
Marble	2500	2.00	802
Screed finish (lightweight)	1200	0.41	840

- Size, shapes, and position of openings including doors and window.
- Treatment of openings, opening arrangement, and protection from heat and water penetration.
- Construction of solid portions of walls.
- Combination of passive solar components such as transparent insulation.

A major decision is whether to use heavy or lightweight construction. Heavy construction is preferable for passive solar design and natural cooling in order to reduce room temperature swings.

Consequently, for the purpose of the subject of this Thesis , external walls for case study buildings in Jordan will be considered heavy weight with high thermal mass. Openings types, sizes and positions and fenestration themes for main facades, with concentration on solar gain requirements, will be tested in the methodological part of the research.

d) Insulation materials:

Appendix B shows the requirements of insulation in buildings mandatory by the Jordanian building codes of practice. Thermal insulation techniques and applications will **not** be covered in detail in this study.

Table (8) shows the thermal conductivity of some insulation materials.

Table 8: Thermal Conductivity of Thermal insulation materials: (Smith, 2006)

Thermal insulation	Thermal conductivity (W/mK)
Expanded polystyrene slab	0.035
Extruded polystyrene	0.030
Glass fiber quilt	0.040
Glass fiber slab	0.035
Mineral fiber slab	0.035
Phenolic foam	0.020
Polyurethane board	0.025
Cellulose fiber	0.035

2-7-4 Fenestration

a) Background:

Fenestration is an essential component of any building enclosure, in the form of windows, glass doors, skylights, sunspaces or atria. It provides the path for visual and psychological communication with the external environment. Design of fenestration systems should consider all factors that affect performance and indoor environment (Athienitis and Santamouris, 2002)

Fenestration, orientation, and shading play a major role in the building's overall energy use through heating and cooling loads in nonresidential and high-rise residential buildings, and can affect the operation of the Heating, Ventilation and air conditioning (HVAC) system and the comfort of the occupants.

One of the elements of the fenestration system is windows. Windows play an important role in the comfort, aesthetic, and energy efficiency of a building. Sunlight is an essential requirement for our everyday life. However, in some climates, windows can be one of the single largest sources of unwanted heat gain and loss in the thermal envelope. Windows typically lose heat through conduction and air movement around the frames.

Generally, the amount of heat gain or loss (as solar radiation or thermal heat) through windows depends on window size, type, orientation, geographic location, and the time of the year. (Sharaih, 2009)

With the development of scientific techniques for estimating natural ventilation, solar gains and natural daylighting it is now possible to design fenestration systems for specific solar gains in winter, exclusion in summer, natural ventilation and daylighting. Many modern building may be over glazed, sometimes for the sake of appearance and sometimes to achieve levels of daylighting.

Nevertheless, this research addresses scientific techniques in estimating the optimal fenestration solutions in regards of solar heat gain, hence energy consumption. Daylight will be covered in theoretical applications only, and natural ventilation will not be taken into consideration.

b) The Window:

1) General:

The window is an opening in the wall, which lets in daylight and provides a view. New advanced methods for applying different thin coatings to glass have revolutionized the window market, and nowadays a window is a building component, which can be used to make buildings architectural energy efficient structures, which was not possible before. (Roaf, et al., 2004)

A window is an important element in the building envelope. As with insulation, the greater the difference in temperature between the outside and the inside of a building, the better the windows will have to be, i.e. the more the number of glazing panes should be.

Windows should be carefully designed as they serve several functions in an energy efficient building. They act as solar collectors, trapping heat from the sun. They also act as ventilators, providing cross ventilation. They are also important lighting tools. However, a window can lose heat five to ten times faster than an equivalent area of wall. Therefore the design of windows should achieve a balance between its functions. (CSBE, 2009)

The principle function of a window is to admit selected portions of solar radiation. Another important property that affects the function of the window is its ability to prevent leakage of heat.

In temperate or colder climates, the side of the building facing the sun should have more windows and the polar orientation very few to prevent excessive heat loss from the cold side of the building. (Roaf, et al., 2004, 97)

Jordan's climate is considered a hot-arid climate, as mentioned in Chapter 4 of this study. However, design of the fenestration systems and windows should be designed as if they are located in temperate or cold climates, due to the higher demand of energy used for space heating compared to cooling of these spacing.

2) Type:

A window "type" is defined functionally by the primary purpose of the aperture, which will determine design decisions on size, shape, position, orientation and any control systems required. (Lerum, 2008). See table (9).

Table 9: Window design requirements based on the function (Lerum, 2008)

Purpose	Design requirements
1. daylighting	Optimum height and size for required daylight factor.
2. Natural ventilation	Positioned in the wall with respect to local wind direction and internal air currents.
3. daylighting and view	Size and sill height above floor level and exterior suited to occupant positions and external features.
4. daylighting and natural ventilation	Sizing and location must be suited to all parameters.

Windows should be designed for their specific purpose, which can be one of the following: Solar gain, light penetration, wind and view. In this research, solar gain will be simulated by the thermal simulation computer software.

Window shapes and sizes are often selected based on preliminary assessment of daylight and view needs: for example, a tall window may provide a view different to that of a wide window with the same area. Sound transmission into a building is usually through windows, especially when they are open.

Sizing of South- or near-South facing windows in relation to thermal mass is usually best based on passive solar heating design principles. East-and West-facing windows should not be too large (not more than 10 percent of the zone floor area) because they allow high solar gains in the morning and the afternoon during summer. (CSBE, 2009)

3) Thermal capacity:

The thermal insulation capacity of a building component is expressed in terms of its U-value, the lower the U-value, the better is the insulation. A traditional double glazed window has a U-value of about 3 $W/m^2.K$. with low emission coatings, windows can be made to have U-values less than 1.

Glazing systems incorporate multiple panes imbedded in sealed insulating edge spacers, separated by insulating gas fills using Argon, Krypton, or other inert gases with lower conductivities than air. These insulated glazing's are surrounded with well-insulated frames and one or more glazing surfaces are multilayer coated for a variety of spectral selective purposes. (McCluney, 2009).

Although most of the construction in Jordan have single glazed windows in the fenestration systems, Double pane windows are a very common window type used in Jordan. On the other hand, triple glazed fenestration system are only used in very limited projects that require high specification regarding glazing, such as in building towers, especially on upper floors.

Table (10) and table (11) shows the U-values of window types in general and in regards of orientation, in sequence.

Table 10: Thermal properties of Glazing (Basic) (Smith, 2006)

Glazing	U-value (W/m²K)
Single glazing	5.6
Double glazing	3.0
Triple glazing	2.4
Double with low E	2.4
Double with low E and Argon	2.2
Triple with 2 low E and 2 Argon	1.0
Double with Aerogel	0.5-1.0

Table 11: Thermal properties of Glazing (with orientation) (Smith, 2006)

Glazing	U-value (W/m²K) with solar gain		
	South	East/west	North
Single glazing	2.8-3.7	3.7-4.6	4.6-5.6
Double glazing	0.7-1.4	1.4-2.2	2.2-3.0
Triple glazing	0.0-0.6	0.6-1.1	1.1-2.4
Double with low E	0.1-0.8	0.8-1.2	1.2-2.4
Triple with low E	-0.5-0.3	0.3-0.9	0.9-1.6

Based on a study done by the Royal Scientific Society of Jordan, in 2008, using a simple model of a building to compare between the effects of using single, double or triple glazing on energy consumption of a building; it was found that double glazing saves up to **(59) percent** of the energy consumption compared with single glazing.

On the other hand, it was found that triple glazing saves only **(12) percent** of the energy consumed when compared with double glazing. Consequently, it is more feasible to use double glazing in Jordanian buildings rather than triple glazing that is not widely spread in the market, and with comparably high costs when evaluated beside the minimal amount of energy it saves. See figure (7).

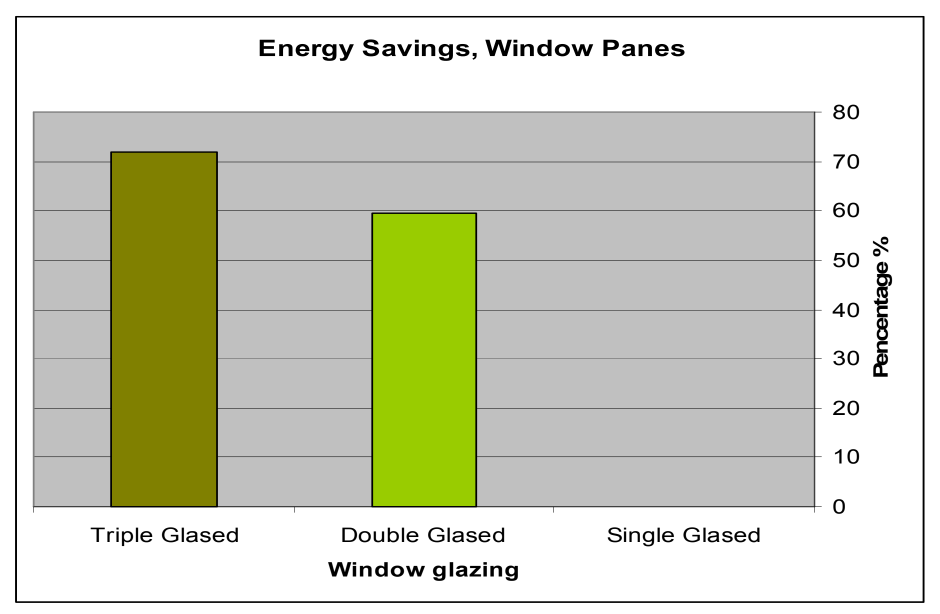


Figure 7: Energy savings percentage when using double and triple glazing in windows, compared to single glazed windows in residential buildings. (RSS, 2008)

It is worth mentioning that this only applies in the Jordanian climate content, and any other regions with similar climatological content. In addition, double glazing works both to prevent heat loss and gain, but does not substitute for external shading. It is cost effective where there are high heating requirements such as in Amman and the western and eastern heights in Jordan. Hence, it is not recommended in the Jordan Valley region and Aqaba city, where cooling loads are only considered, and winters are mild.

4) Solar control glass:

In hot climates, overheating is a serious problem during large parts of the year, and in such cases, solar control glasses can be a greater benefit. These admit as little as possible of solar heat, but are still transparent to visible light. The power needed for air conditioning can in this way be radically reduced. In a global perspective, it is this type of glass which has the greatest energy saving potential, when used in hot climates. (Swedish building research 2/98). See figure (8).

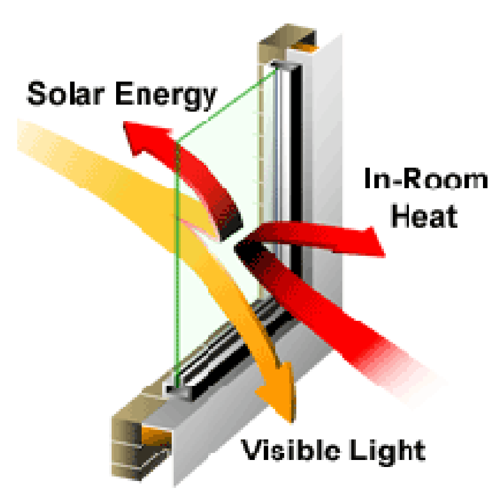


Figure 8: Solar control glass (Smith, 2006)

5) Tinted glass

Tinted glass is effective in reflecting heat in the summer, but also reduces the amount of light and heat entering the room in the winter. It may be useful where large areas of glazing in western and eastern facades are unavoidable. However, they do not substitute for external shading. (CSBE, 2009)

6) Low-e coatings in windows

A low emission coating consists of a thin metallic film, less than one thousand of a millimeter in thickness. This film has the characteristics of reducing outward radiation of heat while at the same time it is transparent to solar radiation.

A low emission coating on one of the panes can almost completely eliminate heat leakage, and in hotter climates they will continue to keeping the building cool. It also can in actual fact contribute to the heating of a building, instead of being the weakest link in the building envelope. (McCluney, 2009).

This kind of Low-e glass is available in the Jordanian Market, so it would be most feasible to use the Low-e coating for glasses in the project of the thesis.

7) Heat reflecting and heat absorbing glazing

These products are usually considered for application in situations where overheating poses a risk. Visible light and solar heat gain are both parts of the electromagnetic spectrum of energy emitted by the sun. The interaction of glazing with light and solar heat has three components: reflection, absorption and transmission. (Smith, 2006)

8) Position and orientation:

Vertical windows on the southerly exposures of buildings can become very valuable sources of heat in winter because of the favorable solar angles and irradiation intensities which prevail from October to April. Fortunately, the excessive input of solar heat which might be anticipated during the summer months is relatively easy to control because of the high solar altitudes during the midday hours. The interior shading which is needed to provide insulation during the summer. Double clear glass admits light as well as heat, but excessive solar radiant energy can be deflected back outdoors by the use of highly reflective shades or drapes. (Watson, 1979)

c) Daylighting:

1) General:

Energy efficient building should make as much beneficial use of naturally available light as possible. Lighting is important because of the influence it has over occupant experience.

Until about 50 years ago, the use of windows and plan form of building was very much influenced by the limits of natural light admission. The development of the fluorescent tube lamp made the deep plane office a feasible proposition but at the expense of noise pollution and frequency band discomfort. There was the added psychological penalty of reducing access to day-light and external views. It is only relatively recently that the importance of these benefits have been acknowledged. (Smith, 2006)

In order to reduce the energy required for lighting, buildings should be designed for adequate daylight, although improved daylighting can increase energy demand for cooling and/or heating (Der-Paterssian and Johansson, 2000)

Appropriate fenestration and lighting controls are used to modulate daylight admittance and to reduce electric lighting, while meeting the occupants' lighting quality and quantity requirements.

2) Benefits of Daylighting:

Lighting and its associated cooling energy use constitute 30 to 40 percent of a commercial building's total energy use. Daylighting is the most cost effective strategy for targeting these uses. Both annual operating and mechanical system first costs can be substantially reduced. (Ouhrani, 1999)

Additionally, daylighting is a beneficial design strategy for several reasons:

- Pleasant, comfortable daylighted spaces may increase occupant and owner satisfaction and may decrease absenteeism. Productive workers are a valuable business asset.
- Comfortable, pleasant, daylighted spaces may lease at better-than-average rates.
- Comfortable, pleasant spaces typically have lower tenant turnover rates.

- Energy-efficient, daylighted buildings reduce adverse environmental impacts by reducing the use and need for power generating plants and their polluting by-products.
- Daylight contributes to a more sustainable design approach.

3) Light penetration:

The most important property of glass, as far as solar energy technology is concerned, is its ability to transmit the shortwave radiation that comes from the sun.

Figure (9), the solar radiation spectrum at sea level on a clear day when the sun is directly overhead (the air mass is 1.0), shows that the invisible ultraviolet portion shorter than 0.4 μm in wavelength contains only about 5 percent of the total solar energy. This small fraction is very important, however, because it is responsible for the fading of fabrics, the deterioration of paints and polymers and, in some cases, skin cancer. Most clear glass transmits about 50 percent of the ultraviolet energy and, while the glass itself is not harmed, drapes, rugs, upholstery and other fabrics exposed to this radiation will generally deteriorate rapidly unless some kind of protection is provided.

Only the spectral range between 0.4 and 0.7 μm can be detected by the average human eye, and so it is called "visible". Only the radiation between 0.4 and 0.7 μm is properly termed "light" or "sunlight", and it accounts for about 47 percent of the total solar energy that reaches the earth. (Watson, 1979)

The transmittances of glass is dependent upon the wavelength of the radiation striking it. Visible transmittance is quite high, as is transmittance in the near infrared, out to the end of the solar spectrum at 2.8 to 3.0 μm. At that point, for thicknesses of 1/8 in. and above, transmittance falls abruptly to virtually zero and none of the longer infrared is transmitted. (Watson, 1979)

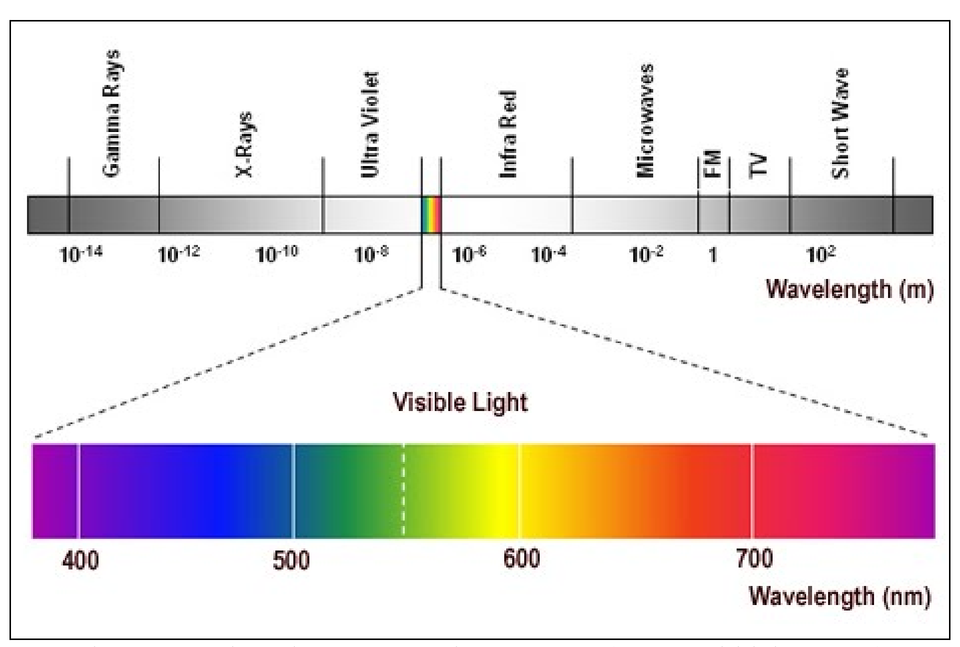


Figure 9: Solar, electromagnetic spectrum (Hazzwold labs, 2011)

Radiation at the infrared wavelength is entirely absorbed by ordinary glass and this gives rise to the “greenhouse effect”, by which solar radiation is trapped when it enters an enclosed space through a glass window. The incoming radiation is absorbed and converted to heat by surfaces which then become radiation sources. The radiant energy absorbed by the window raises its temperature until the absorbed energy can be dissipated, primarily to the outdoor environment, and so it is incorrect to say that none of the entering radiation escapes. However, the amount that escapes is much less than if the window were unglazed or if the glazing were transparent to the infrared radiation. (Watson, 1979)

4) Daylighting Factors:

As one of the largest energy sinks for commercial and industrial buildings, lighting justifies special treatment. Furthermore, with buildings becoming increasingly energy efficient in terms of space heating so the lighting load become of greater significant. It will be some time before we realize the revolution in lighting promised by developments in light emitting diodes. (Smith, 2006)

The time and distribution of light internally are affected by the ratio of total window surface to the area of the internal space. This is termed as the fenestration, expressed as a percentage.

Size of the window can be classified according to table (12) based on human scale, while the penetration of daylight through a window in relation to space area can be classified according to table (13). However, the amount of light penetrated through glass is determined by the type of glazing used in the fenestration system and their visual transmittance properties as mentioned in table (14).

5) Daylighting strategies:

*** Area:**

The amount of glazing has a clear influence on the amount of daylight available, but more window area is not always better, it may simply increase contrast. Large windows admit light but also provide heat gain and heat loss routes and thus successfully will require consideration of the issues at the building planning stage. The amount of sky which can be seen from the interior is a critical factor in determining satisfactory daylighting.

In non-domestic building, the window area should be about 20 percent of the floor area to provide sufficient light to a depth of about 1.5 times the height of the room. (Lund and RSS, 2009)

Where single sided daylighting is proposed, the following formula gives a limiting depth (L) to the room. (Smith, 2006)

$(L/W) + (L/H) <= 2/(1- Rb)$

Where L= room depth, m

W= room width, m

H= height of top of window, m

Rb= average reflectance of internal surfaces

Table 12: Size classification of window (Ouhrani, 1999)

Classification	Surface area (m)
Small	<0.5
Medium	0.5-2
Large	>2

Table 13: Classification of fenestration as percentage of room surface area (Athienitis and Santamouris, 2002)

Classification	percent	
Very low	<1	Risk low illumination, especially in low overcast skies, atmospheric pollution or external obstructions occur
Low	1- 4	Problems with thermal control and glare unless controls used
Medium	4-10	
High	10-25	
Very high	>25	

Table 14: typical visual transmittance of glazing (ASHREA, 2009)

Glazing type (8mm thick pane)	Typical Visual transmittance	Glazing type (8mm thick pane)	Typical Visual transmittance
Single pane clear	0.89		
Single pane tint- green or blue-green	0.70	Double pane tint- bronze	0.47
Single pane tint- blue	0.57	Double pane tint- grey	0.39
Single pane tint- bronze	0.53	Double pane light reflective	0.30
Single pane tint- grey	0.42	Double pane medium reflective	0.20
Single pane tint- extra dark	0.14	Double pane high reflective	0.10
Single pane light reflective	0.35	Double pane low-E clear	0.70
Single pane medium reflective	0.25	Double pane low-E tint- green or blue-green	0.63
Single pane high reflective	0.12	Double pane low-E tint- blue	0.49
Double pane clear	0.80	Double pane low-E tint- bronze	0.45
Double pane tint- green or blue-green	0.65	Double pane low-E tint- grey	0.37
Double pane tint- blue	0.51	Suspended low-E film products	0.27- 0.60

* **Location:**

High window heads permit higher lighting input as more sky is visible. External obstruction /buildings which subtend an angle of less than 25 to the horizontal will not usually exclude use of natural daylight. If there are many external obstructions the room depth should be reduced. Daylight normally penetrates about 4-6 m from the window into the room. Adequate daylight levels can be achieved up to a depth of about 2.5 times the window head height.

* **Skylights:**

Skylights, or rooflights, give a wider and more even distribution of light but also permit heat gains which may cause overheating. Generally skylight provide about three times the benefit of an equivalently sized vertical window. Skylights spacing should be one to one-end-a-half times the ceiling height. Even though skylights reduce the need for artificial lighting, they cause significant heat loss in winter and heat gain in summer. To limit these effects, skylights should be double-glazed, and should be shaded in the summer. (Lerum, 2008)

* **Internal materials:**

Internal reflectance should be kept as high as possible. This can be accomplished by using very light colors for internal finishing of walls, floors and ceiling, in addition to using light colored furniture and proper positioning of the internal elements. (Johansson, 2006)

* **Light shelves:**

The benefit resulting from the use of light shelves is to increase daylight penetration deeper into the building core. Furthermore, light shelves can reduce cooling loads due to a reduction of solar gains. There are two types of light shelves, internal and external: (Athienitis and Santamouris, 2002)

- Internal light shelves provide less daylight penetration than the external ones, under all types of sky, except when direct sunlight impinges on them. In this case the shade a portion of the space close to the aperture. However, since this type of shelf does not shade the glazing surface, cooling load reduction is negligible.
- External light shelves improve daylight penetration under all sky types. The performance of light shelves varies with the reflectance of the upper and lower surface. A highly reflective material can cause glare.

Light shelves have been in use for some time and serve the dual purpose of providing shade and reflected light. Sunlight is reflected from the upper surface of the light shelf into the ceiling where it provides additional diffuse light thus helping to provide uniform illumination. Under conditions of an overcast sky, light shelves cannot increase the lighting level. They operate most effectively in sunlight. Problems with low angle winter sunlight penetration can give rise to glare. Difficulties can be experienced in cleaning the light shelves, especially the external type. Figure (10) shows how the light shelve can separate the window by function.

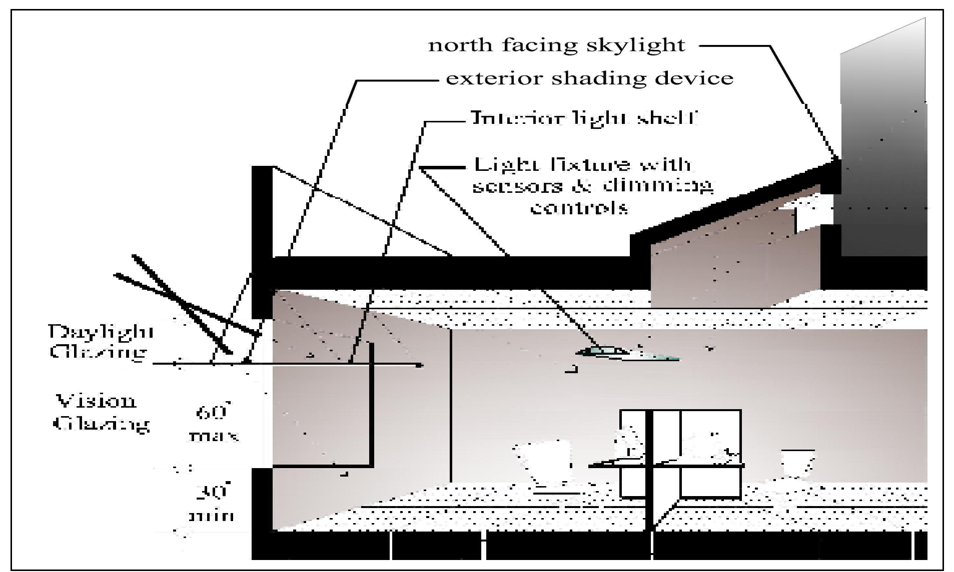


Figure 10: Day lighting strategies, including the light shelve. (USGBC, 2010)

6) Conclusions for daylighting:

Table (15) shows the properties of glass, such as Total Solar Transmittance, Shading Coefficient and U-Value for Clear Single and Double Glazing Using ⅛ inch- and ¼ inch- Thick Glass, with ½ inch of Air – Space Width.

Table 15: glass properties (Watson, 1979)

	Single Glazing		**Double Glazing**	
Thickness (cm.)	3	6	3	6
Solar Transmittance	0.86	0.78	0.71	0.61
Shading Coefficient	1.00	0.94	0.88	0.81
U-Value, $kWh/m^2.K$	6.246	6.246	2.78	2.78

In conclusion, principal factors influencing levels of daylight are:

- Size and amount of glazing,
- Orientation of windows;
- Angle of tilt of windows;
- Obstruction to light admission (e.g. nearby building)
- Reflectivity of surrounding surfaces.
- Glazing properties

Current wisdom has it that office design should optimize natural lighting. One reason for this is that lighting is often the largest single item of energy cost, particularly in open plan offices. Another factor is that occupants tend to prefer natural light, especially since certain forms of artificial lighting have been implicated as the source of health problems. (Smith, 2006).

d) Window shading:

1) General:

Most glazed areas in both residential applications and in some nonresidential ones have some form of shading for privacy, glare control, and to mitigate solar heating when that is a problem. Most effective are operable shading devices, such as venetian blinds and vertical slat shades that are adjustable.

For maximum energy performance, these products must be adjusted regularly, either by human control or by some form of automated management system. Automated management, properly designed and programmed, can be very effective, but are typically expensive and not that often used. As energy prices rise, however, more of these will come to market and increased usage can be expected. (McCluney, 2009).

The best way of avoiding overheating in hot climates is to minimize the transmission of solar gains into the building interior. In considering facades, solar shading featured as an integral element in the facade glazing. More common are external shading devices which are confined to the southerly elevation. Additionally, exterior shading is always more effective than interior shading. (Smith, 2006).

Some shading devices offer a lot of flexibility, e.g. an external blind with insulated louvers can offer shade while allowing natural ventilation when the louvers or slats are rotated to the correct angle.

It is important not to make unshaded windows too large, to prevent over-heating in a building. With climate change the sun will get stronger and rooms that are exposed to the direct sun in summer will have a problem. Shade all windows in summer, should all be shades. It is also very important to design for solar control through windows to let the sun penetrate in the colder season. (McCluney, 2009).

2) Types of shading:

* **External Overhangs:**

Optimal angles of shading devices can also be very effective in providing good vision from inside to outside spaces. It is essential that this factor be tested to make sure that the shading devices do not block the visual line. By integrating the heat gain, the illuminance levels, and the viewing possibility through windows, the quality of architectural spaces will be enhanced as well. (Al-Zoubi, 2009).

The optimal angles can simultaneously provide good daylighting and minimum heat gain in spaces simultaneously. It is recommended that architectural designers be fully aware of this fact. Having flexible range of illuminance level gives high margin of choosing a good blind angle for minimum heat gain. (Al-Zoubi, 2009).

* **Shutters:**

Shutters can be used externally to control solar gain in hot climates at different times of the day and year. Shutters can be used internally in cool and temperate climates to keep excessive sunlight out but warmth in. It can be wind-permeable but still keep the sun out. Once the light has passed through the glass the heat it contains is trapped inside the room and will not escape back out. (Roaf, et al., 2004)

* **Venetian Blinds:**

Venetian blinds are usually used on the outside of the lower window strop; a central control system closes the blinds in the morning when necessary, while during the day they are operated manually by the user.

* **Externally Installed Blades**

The use of externally installed blades changes the entire appearance of the building. The lower part of the blades can be closed to avoid direct solar penetration. The upper part can be adjusted horizontally to reflect daylight deeper into the room. Daylighting levels are increased by up to 30 percent at 4 m distance away from the external wall. This device can be used in conjunction with inclined reflected ceiling in order to increase daylight levels on the working surface. (Athienitis and Santamouris, 2002)

* **Interior shading**

Internal window treatments- curtains/ blinds: These are important in reducing winter heat loss, but are not effective in blocking the summer sun. In order for curtains to act as an insulator, they should be made of a heavy fabric with insulating backing. They need only to be long enough to reach the ground, and they should include a closed pelmet to minimize air circulation between the curtain and the glazing. (CSBE, 2009)

* **Automotive shading devices:**

Such shading is not limited to interior, operable devices. Both fixed and operable between-the-glazing shades and exterior shade screens and shutters can also be effective glare and solar heat gain management strategies. Most of these devices are strongly directionally selective. Some shading applications also reduce conductive and convective heat transfers through windows. One system in development offers automated movable insulating exterior shutters which can greatly increase the thermal resistance, impact resistance, and solar heat gain prevention when closed at night, during extreme weather events, and when the room is unoccupied. (McCluney, 2009).

3) Glare control:

The problem of glare should be considered in the design, In particular, high glare levels will make it difficult to read computer screens and view the TV. Glare is also an indication to very high day lighting levels that may indicate that rooms will also overheat in summer. (Roaf, et al., 2004)

This aspect cannot be simulated by simulation programs, although, traditional methods should be taken in consideration for controlling glare in designing internal and external shading devices.

2-7-5 Other technologies

Climate facades: the glass curtain wall is a familiar feature of office. The technique was conceived at a time when energy was cheap and plentiful and there was no glimmer of global warming. Building challenged the environment. Now there is mounting pressure to design buildings that operate in harmony with nature, making the most of solar resources.

The demand for increasing energy efficiency led first to the introduction of double-glazing. Now things have moved on with the incorporation of a second inside skin of glazing creating what is termed a 'climate façade' or alternatively an 'active façade'. (Smith, 2006)

Double skin facades have become a major architectural element in office buildings over the last decade, to reduce the use of artificial light in a building and increase the light from sun. this can create opportunities for maximizing daylight and improving energy performance. The extra skin offers improved insulation, which both can reduce cooling demand in summer and heating demand in winter. (Alghoul et.al, 2009)

The double-skin façade is an architectural phenomenon driven by the aesthetic desire for an all-glass façade and the practical desire to have natural ventilation for improved indoor air quality without the acoustic and security constraints of naturally ventilated single-skin facades. A second layer of glass placed in front of a conventional façade reduces sound levels at particularly loud locations, such as airports or high traffic urban areas. (Lee, et.al, 2002)

Operable windows behind this all-glass layer compromise this acoustic benefit, particularly if openings in the exterior layer are sufficiently large to enable sufficient natural ventilation. Another cited benefit is that double-skin facades allow renovation of historical buildings or the renovation of buildings where new zoning ordinances would not allow a new building to replace the old with the same size due to more stringent height or volume restrictions. The second layer of glass provides opportunities for heat recovery during the cold winters and heat extraction during the summer. Shading systems placed within the interstitial cavity are protected from the weather. (Lee, et.al, 2002)

Thermal comfort is purported to be improved with this buffer space compared to conventional window systems. The complexities and design variations of double-skin facades are large, requiring significant engineering expertise to design well. (Lee, et.al, 2002)

The active façade fulfils a variety of functions, it:

- offers room daylight control;
- acts as an active and passive solar collector;
- offers excess solar heat protection;
- minimizes room heat loss;
- Facilitates heat recovery.

This type of façade, the double skin façade, will not be tested in this research. This is due to the fact that infill-commercial buildings investors and owners in Amman wish to utilize every meter square of area they can for investment. On the other hand, double skin facades widths usually range between 0.5 and 2.00 meters, depending on the height of the building and type of environmental control desired inside the building. Consequently, this would be (lost space) for investment and would not be offset when compared with the energy savings resulted when using such strategy. Therefore, the use of double skin facades are not recommended for this type of buildings in Amman, based on financial feasibility.

(II)-8

THERMAL SIMULATION

2-8-1 Background:

Instead of massive experimental buildings, today's techniques offer computer simulations as a relatively cheap method of pre-testing new building concepts or materials. Programs to be used in *research* require a great deal of knowledge to enter the input data and interpret the results correctly. They need to be validated through measurements of real buildings. This is especially important when working with non-conventional building design. (Rosenlund, 2000)

The use of physical scale models in architectural design is often an integral part of an experimental or exploratory approach. It is also important to see modeling as an explanatory activity that will be helpful in creating visual images in the process of conceptualizing the problem. (Lerum, 2008)

Modeling can be used to arrive at a clearer understanding of the problem. It is often said that a clear description of the problem brings you more than halfway to its solution. For architects, modeling may be used as a visual tool of explanation. (Lerum, 2008)

2-8-2 Definition:

A model is a simplified representation of the real world. Models may act as intermediaries between theory and hypotheses. The usefulness of models can be evaluated from how well they perform in these areas: (Lerum, 2008)

- Formulating hypotheses
- Explaining phenomena and data
- Making predictions
- Pointing to conditions for change

2-8-3 Objectives:

Computer analysis of energy flows in buildings has offered new understanding of the interaction of building materials exposed to daily and seasonal climatic variation and to changing conditions of use. Computer-aided energy design now offers the building designer new methods by which to develop a solution for the specific environmental control requirements given by each site, orientation, and internal building program.

As a result, computer-aided techniques could become an essential part of energy conservation in building design. These new techniques have an obvious impact on the way that architects and mechanical engineers coordinate their work during the design process, as well as on the way that the designer organizes the conceptual design process so that it interacts with computer programs.

Given the increasing availability, flexibility, and lower cost of computers, we are near the point where lack of familiarity by the professional with computational and graphic display possibilities may be a significant barrier to improved energy design practice. (Watson, 1979)

2-8-4 Parametric modeling:

An organized way to study the energy balance by computer tools is to carry out a parametric study. Hence, each building parameter may be systematically evaluated in terms of its effect on the energy balance. (Rosenlund, et. al, 2005)

The parametric modeling study is a process where the influence of each parameter (such as orientation, window size, building materials, or ventilation) on the indoor climate or energy consumption is assessed. This process can also be referred to as what-if scenarios; connecting theories with hypothesis through testing and experimentation.

After a first stage with systematic studies of each individual parameter, a more intuitive process normally follows, where combinations of parameters are studied. The objective is system optimization or best possible solution- not optimization of individual elements. (Rosenlund, 2000)

The benefit of performing what-if scenarios and analyzing their effect in building energy simulation programs lies in the comparison of alternative solutions. Although the actual numerical output may be less reliable, the relative differences in a series of iterations are valid as criteria for selecting which solution will create the most energy savings. It is also important to keep in mind that the types of what-if scenarios described here should primarily be seen as decision-making tools, rather than as actual predictors of the annual energy use, indoor air temperatures, or other related parameters. (Lerum, 2008)

2-8-5 Possibility of studies

The main purpose of the design tool is to be a simple but still accurate design aid to study the energy performance of buildings for varying designs. The intention is to make the tool sufficiently advanced to produce relevant data, but not so complicated that the user introduces unnecessary errors in the input data. The calculations are based on a detailed, dynamic thermal model. The tool is mainly used for research and teaching, but can with advantage be used by architects, engineers and other consultants participating in the building design process.

It is important to understand that creating a program for what-if scenarios to be investigated involves more than identifying scenarios that may cast new light on significant performance parameters.

Once a list of scenarios has been established, a plan for the execution of the scenarios must be made, including the types of computer models to be created and tested. Ideally, any computer model set up to test the performance parameters of a what-if scenario should also be plugged into, or communicating with, the 3-D building model, thus becoming an integral part of the building information management system. (Lerum, 2008).

In order to create results and outputs that are related to energy consumptions and conservation methods and strategies, the simulation inputs should include the following:

- Climate and site (geographical location)
- Orientation and geometry of the building
- Material properties (thermal and optical)
- Solar gains
- Shading screens
- Internal Loads
- Ventilation, Infiltration

2-8-6 Limitations:

Some ordinary design tool simulation programs are simpler but offer limited possibilities for modeling and calculation. Sometimes the algorithms assume a steady state and do not calculate dynamic processes, while others do not account for the effects of thermal storage.

These simpler programs are often considered valid for their limited use, as an aid in the design of ordinary buildings, and they may even be certified for official use, such as for energy balance estimates in building permit applications.

Integration with other programs, and further development of computers could make the ‘design-oriented’ simulation programs more reliable, and usable early in the design process. Expandable data bases, based on simulations, rules of thumb, expert systems, and heuristic models, integration with CAD and other modules would make both building design and production less expensive and more precise in the future.

What-if scenarios as tested in building energy simulation programs are useful supplements to the intuitive sketching method in the same way that three-dimensional modeling programs provide useful feedback on massing and shading effects of multiple iterations to the project design.It is important to understand that building energy simulation models, like any computer tool, will only generate quality output if the input also meets high quality standards. In general, the output is less reliable for the more simplified models. This does not mean that simplified energy models used to generate what-if scenarios are invalid. (Lerum, 2008)

2-8-7 Computer simulation programs:

a) General

Although there is a large number of building simulation available in the market, most of the tools start from the same level and are used in similar manner. They are used for code compliance checking and thermal load calculations for sizing of HVAC systems. (Hopfe and Hensen, 2005).

The effect of day lighting and external heat gains resultant from the pre-selected external thermal insulations, and window to wall Ratio (WWR) on the energy use and also the evaluation of both visual and thermal comforts can be numerically modeled using Hourly Analysis Program (HAP), Visual-DOE programs package. (Hassan and Fahim, 2009)

Simulation tools are neither used to support the generation of design alternatives, nor to make informed choices between different design options, and they are neither used for building and/ or system optimization. Building performance simulation could/ should be used in a way of indicating design solutions by for instance numbers and graphs, introducing an uncertainty and sensitivity analysis for guidance, supporting generation of design alternatives, providing an informed decision making: choices between different design options and last but not least building and/ or system optimization. (Hopfe and Hensen, 2005).

Moreover, it is desirable to evaluate the building response under extreme weather conditions for many design options, each time changing only a few of the building parameters, until an optimum response is obtained. Thus, it is desirable to have efficient simulation and design tools that can be used for routine passive solar analysis. (Athienitis and Santamouris, 2002)

b) Requirements:

The simulation program should be a computer-based program for the analysis of energy consumption in buildings and be approved by an authority having jurisdiction. The simulation program should model the following:

- Energy flows on an hourly basis for all 8760 hours in the year,
- Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays,
- Thermal mass effects,
- Thermal zones,
- Part-load and temperature dependent performance of heating and cooling equipment,
- All of the standard design characteristics specified in this building.

The simulation program shall use hourly values of climatic data, such as temperature and humidity from representative climatic data, for the city in which the proposed design is to be located.

Several computer programs are available for the purpose of predicting building energy use, with a wide range of capabilities and costs. The key factor in selecting a program is its ability to handle the specifics of the building being evaluated in sufficient detail and with sufficient flexibility to permit study of alternatives in adequate depth. The cost of using these programs for new building design can range from less than one hundred dollars to several thousand dollars, plus about 1 to 10 professional man-days. Once a particular program has been selected, the main items of cost are the number of alternatives to be evaluated, and the complexity of the building and its systems.

c) Example programs:

1) DEROB:

DEROB-LTH, an acronym for Dynamic Energy Response Of Buildings, originates from the University of Texas. It is a design tool with the possibilities of exploring the complex dynamic behavior of buildings for different designs and is used for commercial, research and educational purposes. The tool is under continuous development at the division of Energy and Building Design at Lund University. The form of the building can be modelled in a flexible way with a number of 3D surface geometries, from triangles to five-sided polygons.

The number of zones is maximized to 8. Libraries for opaque and transparent materials and constructions are included and can be modified according to special needs. The program has a semi-transparent building element type that can be used for modeling a shading screen, e.g. an awning.

The calculations, based on an energy balance model, use a time interval of one hour and calculate the different types of building energy performance parameters in response to the hourly values of climatic data, scheduled input for indoor temperatures, maximum power for heating and cooling, internal loads, airflow rates and window openings. (Lund, 2008)

Results that can be obtained from DEROB are as following:

- Indoor, surface and operative temperatures
- Energy demand for heating and cooling
- Peak loads for heating and cooling
- Inflow -and outflow for each volume in the building. The flows include forced ventilation, natural ventilation and infiltration.
- Solar insulation, transmittance and absorption.
- A set of comfort indices like Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD).
- Daylight properties and Sun views of the building.

2) TRNSYS:

TRNSYS (pronounced 'tran-sis'), commercially available since 1975, is a flexible tool designed to simulate the transient performance of thermal energy systems. TRNSYS's beginnings can be found in a joint project between the University of Wisconsin-Madison Solar Energy Lab and the University of Colorado Solar Energy Applications Lab. (TRNSYS, 2010)

More than 25 years later, TRNSYS is a well respected energy simulation tool under continual development by a joint team made up of the Solar Energy Laboratory (SEL) at the University of Wisconsin-Madison, and other respectable research centers in the United States. TRNSYS currently boasts a graphical interface, a library of 80 standard components, add on libraries offering over 300

other components, a worldwide user base and distributors in France, Germany, Spain, Sweden, Luxembourg, the US and Japan.

TRNSYS is a widely used program for modeling passive solar systems. It is a very versatile tool because it can allow you to simulate a wide range of different systems. This makes the tool very powerful, in particular, for parametric simulations. TRNSYS is used by the majority of solar laboratories around the world and has been extensively validated for solar uses. (Roaf, et al., 2004).

3) Parasol:

Parasol is a design tool to study the potential of solar protection for different types of sunshades and glazing systems and their influence on the building energy performance at an early design stage.

Parasol is based on dynamic energy simulations and provides monthly results for the total and direct solar energy transmittance (g- and T- values) of the sunshade and the combination of sunshade and window system and calculates their influence on the building energy performance. The program has post-processors for studies of daylight and thermal comfort. (Parasol, 2010)

The user can select between external, interpane and internal sunshades. Within each such group, a number of different geometries and material properties can be selected. A simple geometric model, which can symbolize a rectangular office module, is predefined. All dimensions can be changed.

Parasol is mainly intended for simulations of buildings like offices, schools and hospitals, but rooms in residential buildings can also be simulated.

Input data for parasol is separated into three parts: Room, Window and Sunshade. The room data includes specification of the site, geometry, and wall constructions. The window data includes window specifications (i.e. specification of the glazing system).

In the sunshade data part, the type of sunshade is selected. Depending on the type of sunshade, more or less input is required. For example awnings need a precise geometric description while fabric screens are assumed to cover the whole window. The fabric color or type must also be specified. The program includes a database of some common fabric types on the Swedish market.

Some additional input data can be given for the calculation of the building energy performance: Control of sunshades, set-points for the indoor temperatures (heating and cooling), internal loads, inlet air temperatures and flows, and the efficiency of the heat recovery system.

For the outputs of this program, the following can be obtained: Tables or diagrams for monthly average solar transmittance (g- and T values), indoor temperatures, energy demands, maximum heating and cooling load, solar insulation, operative temperatures, design days, and energy demands for pre-heating and pre-cooling the room module. Simulated data can be saved to an external file for further analysis in e.g. a spreadsheet program.

Diagrams with contour lines for daylight levels and operative temperatures (or thermal comfort indices Predicted Mean Vote PMV or Predicted Percentage of Dissatisfied PPD) can be drawn when a simulation of the building energy performance has finished.

4) ENVI-met:

ENVI-met is a computer program that predicts microclimate in urban areas. It is based on a three dimensional Computational fluid dynamics (CFD) and energy balance model. The model takes into account the physical processes between the atmosphere, ground, buildings and vegetation and simulates the climate within a defined urban area with a high special and temporal resolution, enabling a detailed study of microclimatic variations. The fact that the program requires limited input

data and that the modeling of the urban area is simple, makes it user friendly. The input data consists of the physical properties of the urban area of study and limited geographical and meteorological data. Summary of input data concerning climate data is:

- Latitude and longitude, Wind speed, Initial air temperature and humidity

Summary of input data concerning Urban design data is:

- Urban geometry, Trees, Building material properties and Soil properties

The model provides a large amount of output data including wind speed, air temperature, humidity and Mean Radiant Temperature (MRT). (ENVI-met, 2011)

5) eQuest®:

eQUEST® is a widely used, time-proven whole building energy performance design tool. Its wizards, dynamic defaults, interactive graphics, parametric analysis, and rapid execution make eQUEST® uniquely able to conduct whole-building performance simulation analysis throughout the entire design process, from the earliest conceptual stages to the final stages of design. (DOE, 2010)

For wizard-based use, virtually no experience with energy analysis is necessary. To use eQUEST's® Detailed Interface, however, knowledge of building technology is required. Experience with other energy analysis simulation tools, especially DOE-2 based tools, is helpful.

The primary users consists of building designers, operators, owners, and energy/LEED consultants. eQUEST® is also widely used by regulatory professionals, universities, and researchers.

Inputs can be provided at three levels: schematic design wizard, design development wizard, and detailed (DOE-2) interface. In the wizards, ALL inputs have defaults (based on the California Title 24 building energy code).

Outputs can consist of Graphical summary reports provide a single-run results summary, a comparative results summary (compares results from multiple

separate building simulation runs), and parametric tabular reports (compare annual results by endues, incremental or cumulative results). Additional output includes input/output summary reports (rule-of-thumb and other indices), non- hourly simulation results (tabular/text DOE-2 SIM file reports), and hourly simulation results (text and comma-separated variable hourly listings for simulation variables).

6) Energy Plus®

EnergyPlus® is a building energy simulation program, designed for modeling buildings with associated heating, cooling, lighting, ventilating, and other energy flows. EnergyPlus® is a whole building energy simulation program that engineers, architects, and researchers use to model energy and water use in buildings. Modeling the performance of a building with EnergyPlus® enables building professionals to optimize the building design to use less energy and water. The software also models heating, cooling, lighting, ventilation, other energy flows, and water use. It includes many innovative simulation capabilities: time-steps less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multi-zone airflow, thermal comfort, water use, natural ventilation, and photovoltaic systems. Read about new features. It is available free from the U.S. Department of Energy (DOE). (EnergyPlus, 2010)

EnergyPlus® builds on the most popular features and capabilities of BLAST and DOE-2 but includes many innovative simulation capabilities including time steps of less than an hour and modular systems simulation modules that are integrated with a heat balance-based zone simulation. Other planned simulation capabilities include solar thermal, multi-zone air flow, and electric power simulation, including photovoltaic systems and fuel cells. Highlights of using EnergyPlus® version 4.0 include Extensive heating, ventilation, and air conditioning (HVAC) input files, heat pump simulations, and Weather processor.

7) Design Builder®

DesignBuilder® is a revolutionary new building energy simulation and visualization tool. Developed for use at all stages of building design, DesignBuilder® combines state-of-the-art thermal simulation software with an easy-to-use yet powerful 3D modeler. (Design Builder, 2010)

DesignBuilder® innovative productivity features allow even complex buildings to be modeled rapidly by non-expert users, and because it uses the Energy Plus simulation engine, results can be more secured.

DesignBuilder® is competitively priced and cost-effective to learn and use, it is suitable for use by architects, consulting engineers, researchers and students. Some typical applications are:

- Calculating building energy use.
- Evaluating façade options for overheating and visual appearance.
- Visualization of site layouts and solar shading.
- Thermal simulation of naturally ventilated buildings.
- Lighting control systems model savings in electric lighting from daylight.
- Calculating heating and cooling equipment sizes.
- Communication aid at design meetings.
- An educational tool.

DesignBuilder® software would be the simulation program used in the thesis research.

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RELEVANT CASE STUDIES

2-9-1 General:

The literature review chapter includes a number of case studies that consist of the following:

1) Available software usage, opportunities and capabilities.
2) Optimization methods.
3) Façade Optimizations and thermal solutions.
4) Previous studies on window sizing and materials for energy efficiency.
5) Previous studies on thermal control methods.

Each case study will include the name of the project/ paper, name of the Designer/ Author, date of production, abstract and idea of the study, and specific-research comments regarding the purpose of using the case study outputs for benefits of the research in hand.

Finally, conclusions and summary of the literature review chapter are presented in paragraph 2-9-8

2-9-2 Case Study No. 1:

Subject: Defining Means and Criteria for Improving Thermal performance and Minimizing Energy Consumption in Buildings in Jordan

Author: Lund University, Sweden, and Royal Scientific Society, Jordan

Date: August 2008

Source: Report 12, Housing Development and Management, Lund University, Sweden

Abstract: The objective of the project was to introduce new climatic considerations and concepts to the Jordanian construction industry in order to develop local methods and techniques for the design and construction of buildings in an environmentally sustainable way. It was decided to use some design tools to simulate and evaluate the different designs of constructions.

The following building element parameters were varied in the simulation: External wall insulation, Roof insulation and Window size and material.

Other parameters, such as the location of the building in an urban context, the U-values of the windows and shading devices are not investigated in this study but it is recommended to include these aspects in future studies.

To study the thermal impacts of these different parameters, the thermal simulation program DEROB was used. The building elements that are not subject to optimization were given fixed thermal properties.

By using the optimized building elements recommended in this study, a saving of 86 percent can be made on the heating load and 26 percent on the cooling load. Hence a total of 72 percent can be saved on the heating and cooling loads.

The thermal requirements investigated for Amman in this project are limited to apartment buildings. The results from the optimization process carried out for the climate of Amman have found the principal requirements to be:

- A U-value for roof to be between 0.5 to 0.7 W/m²K
- A U-value for walls to be between 0.5 and 0.7 W/m²K
- A Window to Floor Ratio (WFR) for a south oriented building to be between 12 percent and 20 percent

These requirements would allow a total saving in energy for cooling and heating of up to 70 percent, compared to an actual apartment.

Comments: The author of the thesis has helped in conducting the project previously stated. The results of this study was for residential buildings. It is not necessary that the results will be similar for commercial buildings, but the method of parametric study can be used for the same purpose on commercial and office buildings. Other aspects not presented in this report could be investigated in the thesis such as shading, different orientations of the building and window materials. (Author)

A similar study using DEROB-LTD on residential buildings was conducted with the experimentation of the sun space effect in residential buildings in Amman. (Al-Any, 2009)

2-9-3 Case Study No. 2:

Subject: Integrating Advanced Façades into High Performance Buildings

Author: Stephen E. Selkowitz

Date: 2001

Source: Building Technologies Department, Lawrence Berkeley National Laboratory Publications, California, USA.

Abstract: Glass is a remarkable material but its functionality is significantly enhanced when it is processed or altered to provide added intrinsic capabilities. The overall performance of glass elements in a building can be further enhanced when they are designed to be part of a complete façade system. Finally the façade system delivers the greatest performance to the building owner and occupants when it becomes an essential element of a fully integrated building design.

This study examines the growing interest in incorporating advanced glazing elements into more comprehensive façade and building systems in a manner that increases comfort, productivity and amenity for occupants, reduces operating costs for building owners, and contributes to improving the health of the planet by reducing overall energy use and negative environmental impacts.

The study also explore the role of glazing systems in dynamic and responsive façades that provide the following functionality:

- Enhanced sun protection and cooling load control while improving thermal comfort and providing most of the light needed with daylighting;
- Enhanced air quality and reduced cooling loads using natural ventilation schemes employing the façade as an active air control element;
- Reduced operating costs by minimizing lighting, cooling and heating energy use by optimizing the daylighting-thermal tradeoffs;
- Net positive contributions to the energy balance of the building using integrated photovoltaic systems;
- Improved indoor environments leading to enhanced occupant health, comfort and performance.

In addressing these issues, façade system solutions must respect the constraints of latitude, location, solar orientation, acoustics, earthquake and fire safety, etc. We find that when properly designed and executed as part of a complete building solution, advanced façades can provide solutions to many of these challenges in building design today.

The single most striking element common to most of these buildings is their highly glazed or all-glass façades. These new façade systems present a significant challenge to the design and manufacturing community. All-glass façades have been promoted in the past as an architectural statement.

Fenestration systems in buildings, ranging from single windows to complete glass façades, share some common performance requirements.

Two Approaches to Façade Control: Size and Scale. Although the image of the perfectly clear, uninterrupted glazing is a common architectural icon it is impossible using currently available technology to provide adequate environmental control with a single layer of glazing. Even switching to a sealed double glass unit with coatings and gas fills will not consistently provide adequate environmental control.

Comments: This study shows the high capabilities of simulation programs to address suggested design strategies that are intended to lower energy consumption in buildings. However, not all the parameters of this study will be addressed in the thesis, only the ones that are related to passive solar heating and cooling design, excluding ventilation studies. Consequently, glass types and window to wall ratios would be chosen for the simulations conducted in this research.

2-9-4 Case Study No. 3:

Subject: Facade design optimization for naturally ventilated residential buildings in Singapore

Author: Wang, L., Wong, H. and Li, S.

Date: 2006

Source: Department of Building, School of Design and Environment Publications, National University of Singapore.

Abstract: Parametric studies of facade designs for naturally ventilated residential buildings in Singapore were carried out to optimize facade designs for better indoor thermal comfort and energy saving. Two criteria regarding indoor thermal comfort for naturally ventilated residential buildings are used in this study. Thermal comfort regression model for naturally ventilated residential buildings in

Singapore was used to evaluate various facade designs either. Facade design parameters: U-values, orientations, WWR (window to wall ratio) and shading device lengths are considered in the investigation.

The building simulation results for a typical residential building in Singapore indicated that the U-value of facade materials for north and south orientations should be less than 2.5 W/m^2 K and the U-value of facade materials for east and west orientations should be less than 2.0 W/m^2K.

From the coupled simulation results, it was found that the optimum window to wall ratio is equal to 0.24. Optimum facade designs and thermal comfort indexes are summarized for naturally ventilated residential buildings in Singapore.

Comments: The same parameters of this study will be investigated in this thesis, but not for the same reasons. This study shows how parametric modeling can be used to serve different objectives using the same parameters and results. Consequently, office buildings in the city of Amman will be simulated and results of energy consumption rates will be compared between cases using the same change in parameters.

2-9-5 Case Study No. 4:

Subject: Influence of Windows on the Energy Balance of Apartment Buildings in Amman

Author: K. Hassouneh, A. Al-Shboul

Date: 2008

Source: Global Conference of Renewable Energy Approaches for Desert Regions [GCREADER] Proceedings, March 31st – April 2nd 2009.

Abstract: The influence of windows on the energy balance of apartment buildings in Amman is investigated by using self developed simulation software (SDS) based on the ASHRAE tables for solar heat gain calculation and coaling load factor for latitude 32°, where Amman city is located. The calculations of energy saving are made to find out the influence of windows on the energy balance of apartment buildings in Amman. Also, the present investigation aimed to study the energy performance of windows of an apartment building in Amman in order to select the most energy efficient windows that can save more energy and reduce heating load in winter, the percentage of saving energy and saving fuel and money through time.

Variations of type of glazing using eight types of glazing (clear glass, Type A, B, C, D, E, F, and G) are made to find out the most appropriate type of glazing in each direction. Also the orientation of window is changeable in the main four directions (N, S, E and W). The area of glazing varies also in different orientation to find the influence of window area on the thermal balance of the building. The results show that if energy efficient windows are used, the flexibility of choosing the glazed area and orientation increases.

It has been found that choosing a larger area facing south, east and west can save more energy and decrease heating costs in winter using certain types of glazing such as glass type A and clear glass, while decreasing the glazing area facing north can save money and energy. However, it has been found that the energy can be saved in the north direction if glass type B has been used. In the apartment building, it is found that certain combination of glazing is energy efficient than others. This combination consists of using large area of glass type A in the east, west and south direction, and glass type B in the north direction or reducing glazing area as possible in the north direction.

Comments: This study was done on residential buildings. The same parameters will be used in this thesis to be investigated in commercial and office buildings in the same climate zone, i.e. in the city of Amman. The results of the thesis will be compared with the results of this study, as part of the discussion chapter.

2-9-6 Case Study No. 5:

Subject: Effect of Window Area on Heating and Cooling Loads in Residential Buildings in Jordan,

Author: Adnan Shariah, Associate professor, Department of Applied Physical Sciences, Jordan University of Science and Technology

Date: 2009

Source: Global Conference of Renewable Energy Approaches for DEsert Regions GCREEDER Procedings, Amman-Jordan,

Abstract: The main objectives of this work are to present the simulation results (using the simulation computer program TRNSYS) of the effects of some window's parameters (such as size and number of glazing) on monthly and yearly heating and cooling loads on residential buildings in two sites in Jordan. One of them is the capital city, Amman (which represent a moderate climate) and the other is the city of Aqaba (the southern city of Jordan which represent a hot climate).

The results of the TRNSYS simulation, for the effect of window size on monthly and yearly heating, cooling, and total loads are investigated from which the following conclusions can be derived:

- The annual cooling loads comprises about 62 percent of the total load for Amman (moderate climate) and about 95 percent for Aqaba (hot climate).
- Window area has negligible effect on annual heating load, whereas it has very strong effect on annual cooling load (for both cities).

- Applying insulation to walls and ceiling decreases the annual total load (for both cities) only when the ratio Awin/Awall is small, whereas when the ratio is big it increases the load for Amman, and has no effect on the load for Aqaba city.
- The effect of window size on total energy is pronounced in summer for both cities.
- Applying double glazing on window has relatively moderate effect on annual total load for both cities especially at large values of Awin/Awall.

Comments: This study was done on residential buildings. The same parameters will be used in this thesis to be investigated in commercial buildings in one of the climate zones only: the city of Amman. The results of the thesis will be compared with the results of this study, as part of the discussion chapter.

2-9-7 RSS Climatic and Green Studies:

a) Background:

Improvement of energy efficiency in the building sector in terms of safe and friendly environmental needs is a newly introduced concept in Jordan. In the past few years however, the Royal Scientific Society of Jordan (RSS) was very much involved in work-related studies in energy efficiency and modeling.

Many of these studies were conducted with the collaboration of well knowledgeable international and national institutes and organizations. It is worth mentioning here, that the author of this thesis, who is a LEED Accredited Professional, and an employee of the RSS, was one of the main and active participant of many of these studies. She has gone through a line of intensive and diverse training courses and work-related experience in energy efficiency studies and modeling. The pages below describe the different type of studies and activities conducted by the RSS and collaborators in Jordan.

b) RSS Study Outcomes, Reports and Publications:

1) Energy Efficient Building Code:

The results of this intensive and thorough work about energy efficiency that was conducted by the RSS and collaborates evolved of publishing a new code titled "Energy Efficient Building Code of Jordan" (MOPHJ, 2010). The code included guidelines regarding minimum requirements for the building envelope to ensure lower energy consumption inside buildings, as well as requirements for all kinds of buildings including commercial ones. (Author, 2010)

2) Green Building Guideline:

In addition, a new guideline titled "Green Building Guideline" was also produced by the RSS in Jordan. The book included chapters about Green building guidelines, as well as on energy efficiency in relation to green buildings.(Author, 2011)

3) The Aqaba Residence Energy Efficiency Project (AREE)

A study was conducted on an experimental building being constructed in Aqaba. Its purpose is to test and demonstrate energy efficient design and construction ideas appropriate to a residential building in a hot-arid climate. Construction of the pioneering project began in early 2007 and it was open for public since mid 2008. The building showcases design elements, use of materials, construction techniques, and technological solutions will be opened for viewing.

A climatic design evaluation was conducted, and computer simulations, using DEROB-LTH software, was used in order to conclude the optimum way to provide a thermally comfortable environment inside the building and to find the most favorable materials and elements that has the lowest energy consumption for cooling in summer. (Author, 2007)

According to the computer simulated cases tested in the study, the best case for saving in cooling energy was the case in which movable shading devices where added. This case saves over 29 percent of the energy consumption in cooling and 32 percent in the total energy consumption throughout the year, when compared with a building built in the traditional ways.

4) Climatic Design for Schools in Jordan

Another study was conducted to investigate the effect of insulation, ventilation and shading on improving thermal comfort inside schools in Jordan.

Proposed designs of schools were submitted by CDM consulting firm, which designed 25 schools all over Jordan in different locations. Each one of them has its own architectural image but all of them have similar components that have specific design dimensions and requirements, and have been replicated in all designs according to site, area, students count and other effecting factors.

Climatic investigation was carried out on the replicated school elements using computer simulation, and results were expressed as comparison of energy consumption with the base design, giving out recommendations that contribute significantly in saving energy and achieving thermal comfort.

According to the investigation, orientation of class rooms played a major role in saving energy. Approximately no energy was needed for heating south oriented classrooms in most parts of Jordan where heating is required. This is due to the high level of solar gain and penetration through south facing classrooms, and the high number of students in a single classroom, which gives high internal loads. Hence, low energy is needed for heating, and sometimes none. Cooling was not addressed in most parts of Jordan due to the fact that classroom are not operated in the hot summer season.

c) Training Programs

Three successful advanced training programs in 2006, 2007 and 2008 were conducted by RSS staff, with the help from Lund University experts. Climatic Design of Buildings in Urban Areas training program considers the issue of climatic design in a sustainable perspective and supports a new attitude towards design and architecture, ranging from urban climatology, via passive building design, to the choice of appropriate building materials. It offers an opportunity for Jordanian architects, engineers and urban planners to gain knowledge within such field. Training on the use of DEROB-LTH simulation program was also provided to the trainees by the author herself.

Additionally, training was done in how to perform measurements of indoor climate and thermal performance of buildings. The main outcomes of the project were presented and discussed at a final seminar held at RSS in 2008. (RSS, 2008)

After developing basic knowledge in energy efficiency and climatic design, and excessively working with DEROB-LTH software for energy efficiency assessment and development, it was time for an update. However, DEROB-LTH software updating needed funding and time, according to the Housing Development and Management department at Lund University, Sweden, where the software was developed. Consequently, the author of this thesis was involved in training in much developed software called Design builder as part of a training program called "Greening Aspects and Energy Performance Simulation of the Buildings", conducted by the US Department of Energy and National Fenestration Rating Council back in October 2009.

2-9-8 Summary:

1) The use of parametric modeling investigates each parameter effect on the building. Whether the effects are related to cost, comfort, energy consumption, or demand; parametric modeling results can be used in different ways in order to confirm a certain theory or hypothesis. Hence, parametric studies is the most appropriate method to help reach the objectives of this thesis, in order to reach organized and well-defined parameters that assure energy efficiency in restricted orientations of facades.
2) Thermal simulations are most encouraged to be used as early as possible in the design phase and not as a checking tool only. This will help in choosing the proper solutions and criteria with relatively low costs and short time.
3) Some simulation tools are highly complicated and technically specific; especially in regards to electromechanical specifications, which can be difficult for an architect alone to use. Therefore, it is recommended that architect-friendly software, with visual representations of the building and minimum material and HVAC knowledge should be used for the assessment of design of energy efficient buildings.
4) The use of double skin facades is a good choice for façade design. However, the cost of such systems must be taken into consideration when measuring the feasibility of application balanced between energy consumption levels and double skin façade system cost. This system will be tested in the thesis as a theoretical choice excluding its cost factor and without automotive control systems.
5) When more than one project's location and climate data are different, research can be done by conducting the same methods and analysis on all of the projects, giving totally different results and conclusions due to the major of effect of the climate data of the location on a project energy consumption total.

6) It is very important to find a tool that not only gives numerical results of the research but also gives a visualized outcome, in order to expand the architect creativity and classify electromechanical solutions and results.

7) Lightshelves proved to increase daylight efficiency and Illuminance level. This element will be taken as a parameter to be tested in the simulation program to know its effect on energy efficiency.

8) Fluid dynamic simulations backup the study of ventilation requirements and control needs. However, this needs special background knowledge, often practiced by electromechanical engineers and experts, and requires specific wind data for each site location, and sophisticated simulation software. That is why ventilation is not studied in the thesis.

9) Although there are a lot of thermal simulation programs available in the market, most of them require high training and high cost. The aim of this thesis is to use user-friendly software. In other words, software useful for architectural design purposes, with visual representation of the energy efficient buildings, with proper material physics, electromechanical and thermal properties background, let alone the cost and availability of the software.

CHAPTER THREE (III)

CASE STUDY of AMMAN

CHAPTER THREE

CASE STUDY OF AMMAN

3-1 General:

In order to establish the case study experiment and reach the objectives of this research, **four** actual cases of infill- commercial buildings were chosen in Amman. Each building has its own unique requirements and function, but the main difference between them is the orientation of their main façades, four different skewed coordinal orientations. Therefore, each building would be addressed separately but with the same method of experiment. Figures (11) and (12) show the four case study building locations and orientation representation.

3-2 Objective:

The objective of the case study simulation experiment is to establish a regulatory base for minimum design requirements that commercial buildings main façades should have, in order to save energy and lower energy demand needed for space heating and cooling. Different elements and parameters would be tested and results determine optimum parameters, beginning from the most optimum, going through the least optimum, indicated by the annual energy consumption results. This creates a number of design criteria organized in descending order, generating a list of design methods for each skewed orientation of a main façade.

The goal of this study is to create on-the-desk proven design samples, for energy efficient commercial buildings with already determined main façade orientation.



Figure 11: Locations of the four buildings. (GoogleEarth®, 2011)



Figure 12: Locations of the four buildings on map. (GAM, 1999)

3-3 Methodology:

3-3-1 General:

Four actual case studies were chosen in the city of Amman to represent the subject of research. Each building is described separately. This include physical description of the building and function related requirements. The actual case will be called “base case”

The baseline cases should be simplified as much as possible to be more generally representative for each of the building types, and to be easier to handle in computer modeling and calculations. The baseline are representative in terms of:

- General building concept: functional lay out, orientation, etc,
- Unit size, roof spans, ceiling heights, etc,
- Sizes, orientation and shading of openings,
- Construction materials.

All four “base cases” are thermally modeled in order to generate how much energy is consumed annually for heating and cooling. Electricity used for lighting and other uses are exempted from this study. Only energy (in kWh/m^2) used for heating and cooling requirements are calculated; in order to give resilient results that can be used for different and future time, without depending either on type of fuel or its ever-changing cost.

From the base line case, the influence of changing one parameter at a time, such as window size, is studied. This can give information on positive/ negative or strong/weak influences, optimum dimensions, etc.

All four “base cases” went through parametric study procedures, all using the same parameters as proposed solutions. Each parameter is studied alone, and all of the results are separately analyzed, subsequently compared together.

Consequently, two or more parameters were chosen to work together into creating an optimum case study solution, in order to reach the most feasible design criteria for energy saving. This again is for the four case studies separately.

Finally, the results from these buildings were translated into real construction and into recommendations, often as rules of thumb, and other times.

3-3-2 Infill Commercial Building Elements

All four case buildings contain basic function, which are:

1) Ground floor: retail shops and warehouses uses.
2) First floor, or Mezzanine floor, connected to the ground floor below it.
3) 4 to 5 floors of typical plans, usually used as offices.
4) Circulation area: including corridors, elevator shafts and staircases.
5) Service areas: including public toilets, janitorial, etc.

Each element will be described separately in the following paragraphs.

3-3-3 Materials

The following are the materials used for buildings elements in the base design case:

1) External Walls:

Figure (13) shows the materials used in the external wall of the actual case. Tables (16) and (17) show each material thermal properties and the total thermal properties of the external wall (without the fenestration part).

The U-value of the non-insulated external wall is **1.838 Wm^2.K**.

Table 16: External Wall (not insulated) components properties. (DesignBuilder®, 2009)

Layer	Name	Thickness (mm)	k-Value W/m.k	Sp. Heat J/kg.k	Density Kg/m^3
1	Jordan Stone	70	2.271	880	2600
2	Cast Concrete	180	1.130	1000	2000
3	Conc. Block (Hollow)	100	0.62	800	1700
4	Cement Plastering	20	0.88	896	2800

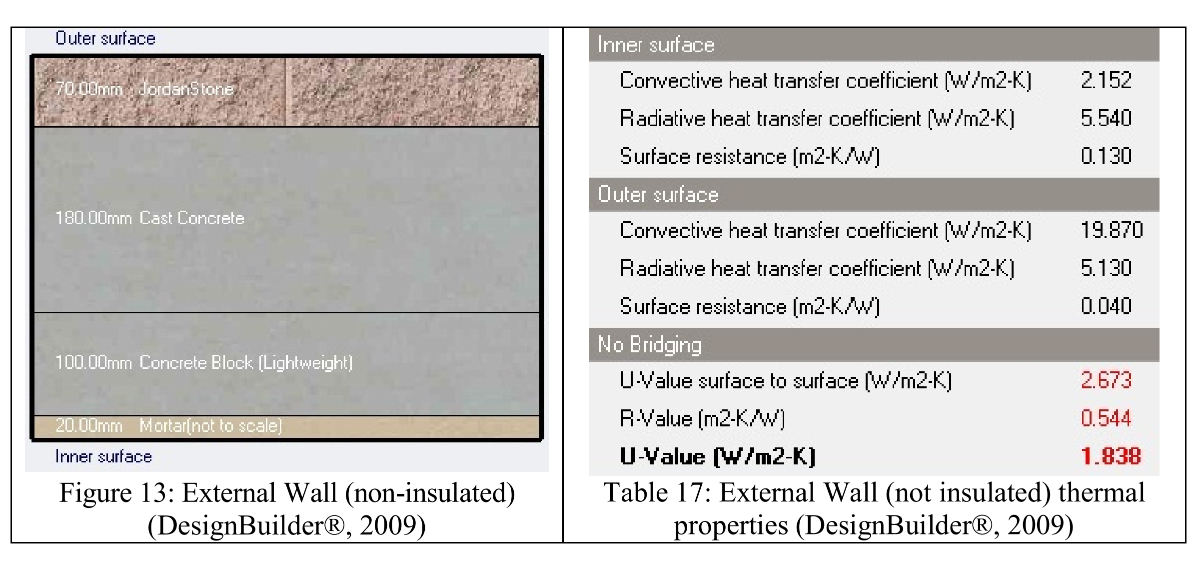


Figure 13: External Wall (non-insulated) (DesignBuilder®, 2009)

Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	2.673
R-Value (m2-K/W)	0.544
U-Value (W/m2-K)	**1.838**

Table 17: External Wall (not insulated) thermal properties (DesignBuilder®, 2009)

2) Roof:

The following figure (14) shows the materials used in the external roof of the actual case. Tables (18) and (19) show each material thermal properties and the total thermal properties of the external roof.

The U-value of the non-insulated external roof is **2.660 Wm^2.K.**

Table 18: External Roof (not insulated) component properties. (DesignBuilder®, 2009)

Layer	Name	Thickness (mm)	k-Value W/m.k	Sp. Heat J/kg.k	Density Kg/m^3
1	Aggregates	100	1	1000	1800
2	Asphalt	10	0.7	1000	2100
3	Reinforced Concrete	250	2.5	1000	2400
4	Cement Plastering	19	0.88	896	2800

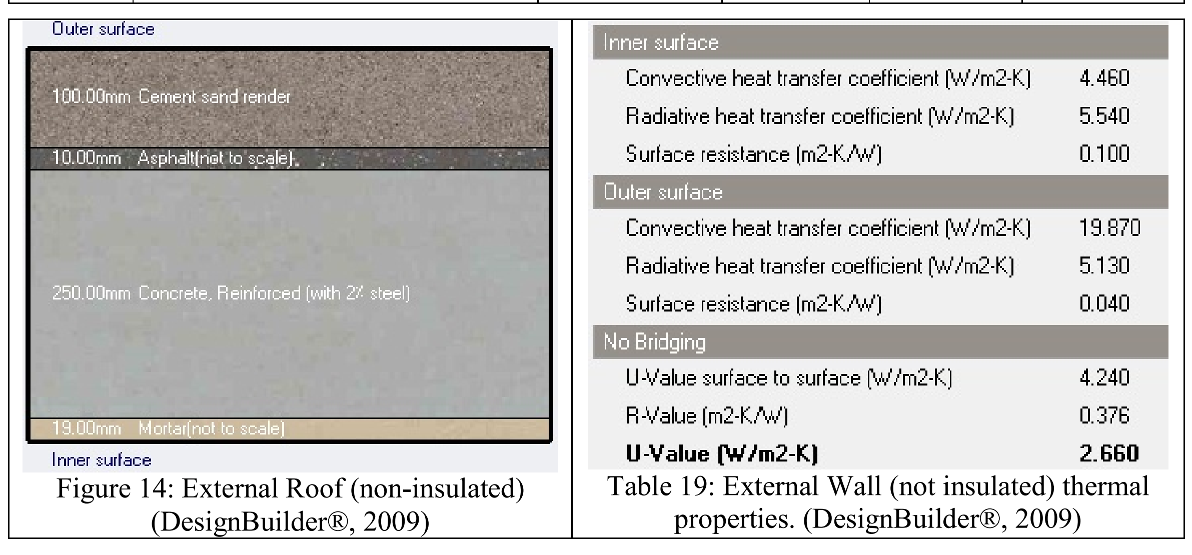


Figure 14: External Roof (non-insulated) (DesignBuilder®, 2009)

Inner surface	
Convective heat transfer coefficient (W/m2-K)	4.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.100
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	4.240
R-Value (m2-K/W)	0.376
U-Value (W/m2-K)	**2.660**

Table 19: External Wall (not insulated) thermal properties. (DesignBuilder®, 2009)

3) Floor:

The following figure (15) shows the materials used in the ground connected slabs of the actual case. Tables (20) and (21) show each material thermal properties and the total thermal properties of the ground connected slab.

The U-value of the ground-connected slabs is **0.732 Wm^2.K**

Table 20: Ground-connected slabs component properties (DesignBuilder®, 2009)

Layer	Name	Thickness (mm)	k-Value W/m.k	Sp. Heat J/kg.k	Density Kg/m^3
1	Compacted Earth	-	1.280	880	1460
2	Gravel and soil	200	0.520	184	2050
3	Concrete Screed	70	0.41	840	1200
4	Asphalt	10	0.70	1000	2100
5	Reinforced Concrete	150	2.30	1000	2300
6	Gravel and sand	100	0.36	840	1840
7	Cement Mortar	25	0.88	896	2800
8	Ceramic Tiling	25	1.30	840	2300

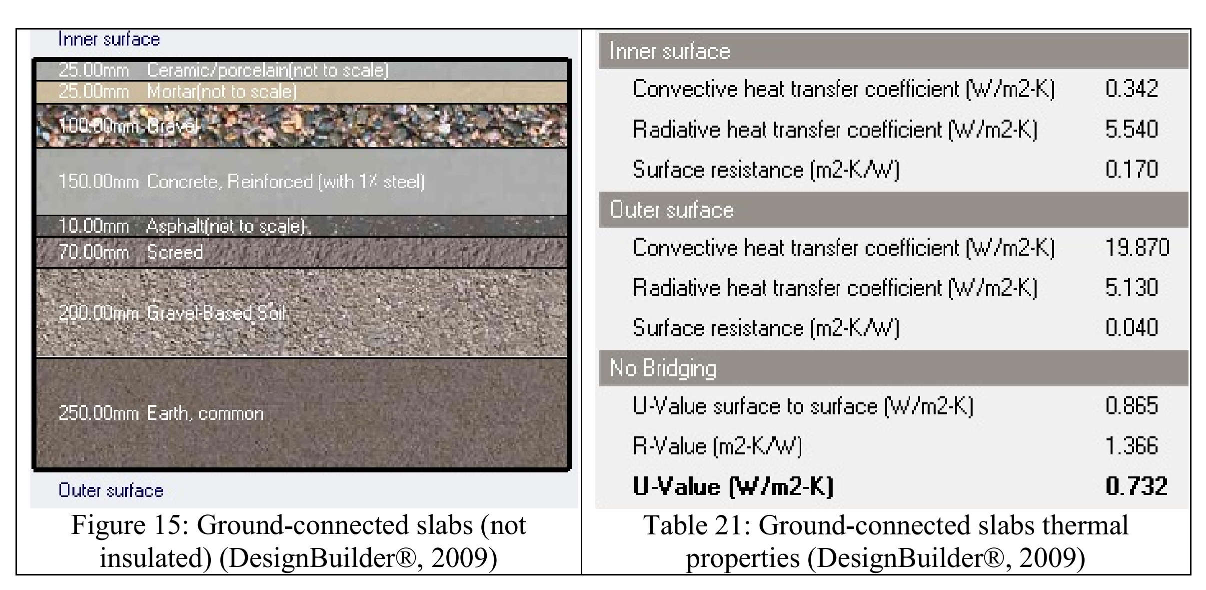


Figure 15: Ground-connected slabs (not insulated) (DesignBuilder®, 2009)

Inner surface	
Convective heat transfer coefficient (W/m2-K)	0.342
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.170
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.865
R-Value (m2-K/W)	1.366
U-Value (W/m2-K)	**0.732**

Table 21: Ground-connected slabs thermal properties (DesignBuilder®, 2009)

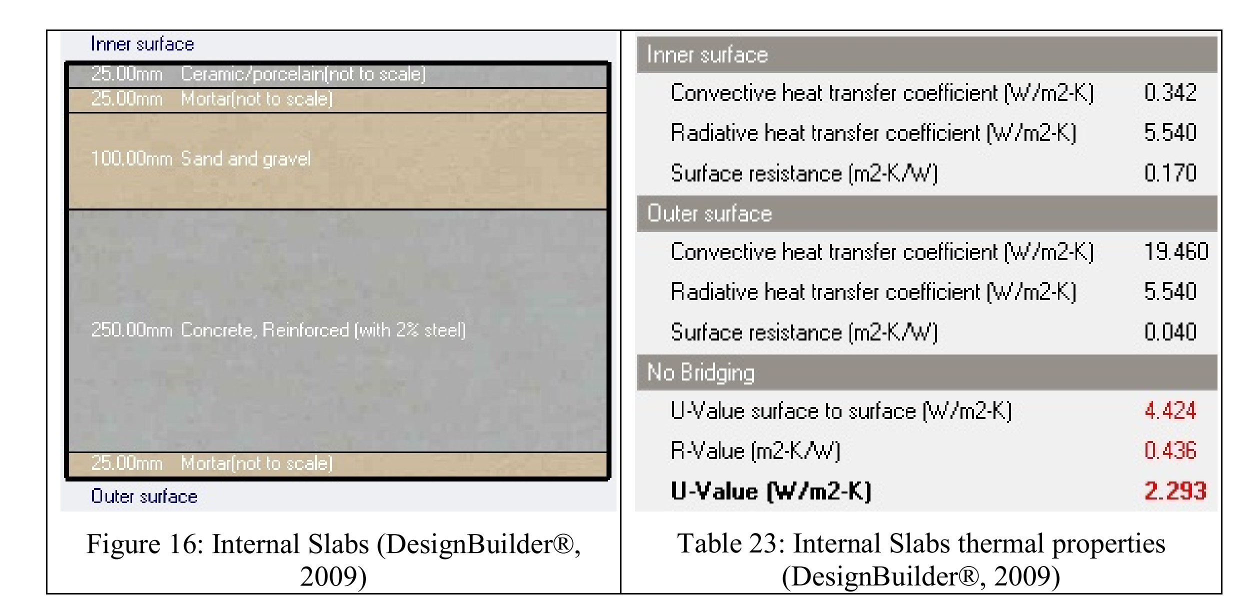
4) Internal Slabs:

Figure (16) shows the materials used in the internal slabs of the actual case. Tables (22) and (23) show each material thermal properties and the total thermal properties of the internal slabs.

The U-value of the internal slabs is **2.293 Wm^2.K.**

Table 22: Internal slabs component properties (DesignBuilder®, 2009)

Layer	Name	Thickness (mm)	k-Value W/m.k	Sp. Heat J/kg.k	Density Kg/m^3
1	Cement Plaster	25	0.88	896	2800
2	Reinforced Concrete	250	2.50	1000	2400
3	Gravel and sand	100	2.00	1045	1950
4	Cement Mortar	25	0.88	896	2800
5	Ceramic Tiling	25	1.30	840	2300



Inner surface	
Convective heat transfer coefficient (W/m2-K)	0.342
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.170
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	4.424
R-Value (m2-K/W)	0.436
U-Value (W/m2-K)	**2.293**

Figure 16: Internal Slabs (DesignBuilder®, 2009)

Table 23: Internal Slabs thermal properties (DesignBuilder®, 2009)

5) Internal Walls:

Figure (17) shows the materials used in the internal walls of the actual case. Tables (24) and (25) show each material thermal properties and the total thermal properties of the internal walls.

The U-value of the non-insulated internal walls is **1.820 Wm^2.K**

Table 24: Internal walls component properties (DesignBuilder®, 2009)

Layer	Name	Thickness (mm)	k-Value W/m.k	Sp. Heat J/kg.k	Density Kg/m^3
1	Cement Plaster	25	0.88	896	2800
2	Concrete Blocks	200	0.62	800	1700
3	Cement Plaster	25	0.88	896	2800

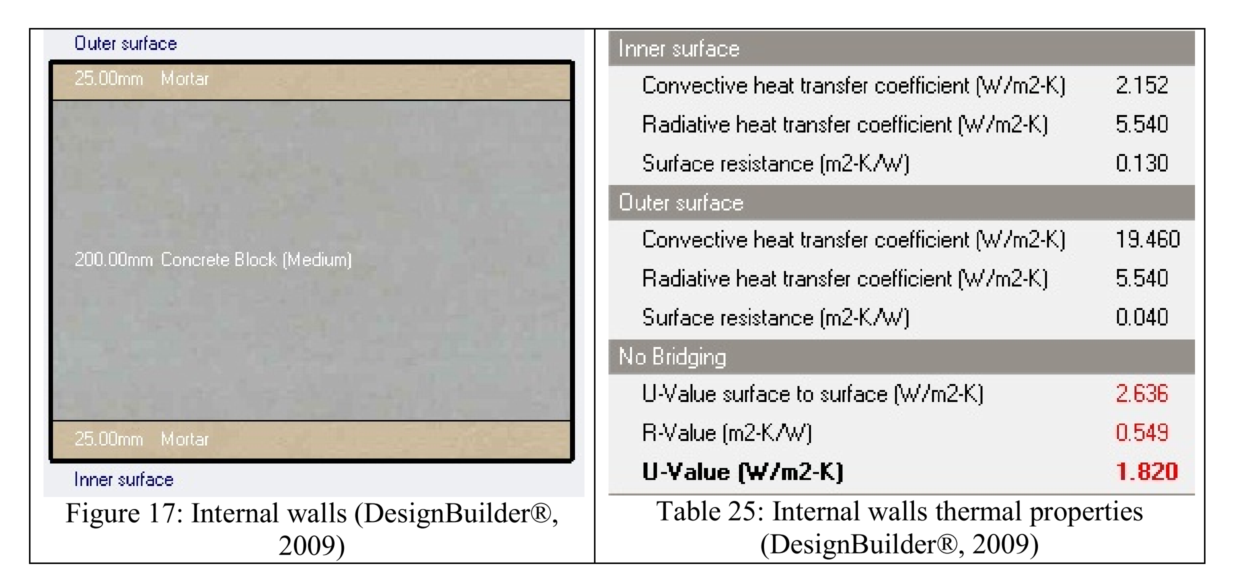


Figure 17: Internal walls (DesignBuilder®, 2009)

Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	2.636
R-Value (m2-K/W)	0.549
U-Value (W/m2-K)	**1.820**

Table 25: Internal walls thermal properties (DesignBuilder®, 2009)

6) Windows:

Colored single glazed windows were used in all four buildings, with a U-value of **6.121 Wm^2.K**. See table (26) for physical properties of 6mm thick single glazing.

Table 26: Single Glazing, 6mm thick (DesignBuilder®, 2009)

Calculated Values	
Total solar transmission (SHGC)	0.810
Direct solar transmission	0.775
Light transmission	0.881
U-Value (W/m2-K)	**6.121**

3-3-4 Activities, Internal Loads, Infiltration and ventilation

Table (27) shows the activity schedules determined for office spaces. This includes occupancy rates per m^2 per day, office equipment internal heat gains expectations, office work schedules (occupied from 8:00 to 18:00, holidays off), and heating and cooling schedules and setpoint. This will affect different volumes with different values of internal loads depending on the activity, and also affecting the timing of the cooling and heating settings.

Table 27: Activity Schedules for office uses. (DesignBuilder®, 2009)

Activity Template	
Template	**Office_OpenOff**
Sector	Office
Zone multiplier	1
☑ Include zone	
Occupancy	
Density (people/m2)	**0.5000**
0 0.5 1 1.5 2 2.5 3 3.5 4	
Schedule	Office_OpenOff_Occ
Metabolic	
Activity	Light office work
Factor (Men=1.00, Women=0.85, Children=0.75)	0.90
Clothing	
Winter clothing (clo)	1.00
Summer clothing (clo)	0.50
Holidays	
DHW	
Environmental Control	
Heating Setpoint Temperatures	
Heating (°C)	22.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30	
Heating set back (°C)	**15.0**
Cooling Setpoint Temperatures	
Cooling (°C)	24.0
-10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30	
Cooling set back (°C)	**25.0**
Ventilation Setpoint Temperatures	
Minimum Fresh Air	
Lighting	
Computers	
☑ **On**	
Gain (W/m2)	**1.00**
0 5 10 15 20 25 30 35 40 45 50 55 60	
Schedule	Office_OpenOff_Equip
Radiant fraction	0.200
Office Equipment	
☑ On	
Gain (W/m2)	15.00
0 5 10 15 20 25 30 35 40 45 50 55 60	
Schedule	Office_OpenOff_Equip
Radiant fraction	0.200

Table (28) shows the activity schedules determined for retail and shop spaces. This includes Occupancy rates per m^2 per day, retail-related equipment internal heat gains expectations, retail work schedules (occupied from 10:00 to 22:00, holidays off), and heating and cooling schedules and setpoint.

Table 28: Activity Schedules for retail uses. (DesignBuilder®, 2009)

Activity Template	
Template	Retail_Typical
Sector	Retail
Zone type	1-Standard
Zone multiplier	1
☑ Include zone	
Occupancy	
Density (people/m2)	0.2500
Scale	0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4
Schedule	Retail_Occ
Metabolic	
DHW	
Environmental Control	
Heating Setpoint Temperatures	
Heating (°C)	21.1
Scale	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30
Heating set back (°C)	15
Cooling Setpoint Temperatures	
Cooling (°C)	23.9
Scale	-10, -8, -6, -4, -2, 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30
Cooling set back (°C)	25
Ventilation Setpoint Temperatures	
Minimum Fresh Air	
Lighting	
Computers	
Office Equipment	
☑ On	

Note: Service and circulation spaces will be modeled by the simulation software but would not be included in energy and thermal calculations and results. Results will only be for regularly occupied areas.

Infiltration rates were averaged annually to be 0.700 ach/m^2; this input will be **constant** for all cases in all four buildings.

3-3-5 Cooling Loads:

For the climate zone in which the city of Amman is located, cooling is needed in office spaces in the summer season. The temperature set for cooling is 25C°, which means that whenever the temperature inside the office (or the shop) is higher than 25C°, the cooling system will operate. This input will be **constant** for all cases in all four buildings.

3-3-6 Heating Loads:

For the climate zone in which the city of Amman is located, heating is needed in office spaces in the winter season. The temperature set for heating is 15C°, which means that whenever the temperature inside the office (or the shop) is lower than 15C°, the heating system will operate. This input will be **constant** for all cases in all four buildings.

3-3-7 Volume Heights:

The height of ground floor areas in all four buildings would be simulated to represent the actual design height which is approximately 3.50m. Mezzanine levels would be considered 2.75 m high, and typical floors height would be 3.15m high. This will be **constant** for all cases in all four buildings.

3-3-8 Climate data:

Climate data including temperatures, wind velocity and direction, solar radiation and rainfall from the Jordan Metrological Data Handbook, (1987), was used in the simulation. August was chosen to be studied for the summer season and January for the winter season. The data is shown in chapter 4 of this thesis.

A special format for the climate data was generated using Metronome Software in order to be able to simulate proper climate data in the DesignBuilder® Software. The closest possible weather data of the site was integrated into DesignBuilder®.

3-3-9 Urban Layout:

All infill-buildings in Amman are commercial or mixed use buildings in which are located in a high density urban development zone. All four chosen building for simulation would be modeled based on their actual urban content surroundings. Building Four (the North-East facing building) is physically attached from one side to another building, in which this option could be simulated by addition of an adiabatic wall connected to that side.

Building One (the South-West facing building) have 2 low-rise adjacent buildings surrounding from each side, with 4 m setback, and no buildings behind it.

Building Two (the South-East facing Building) and Building Three (the North-West facing Building) are both located to face the main street, 3.5m setback distance from an adjacent high-rise building from one side and open to a 12m wide secondary road from the other side. No buildings are located behind the buildings.

3-3-10 Study Parameters:

Based on the literature review and theoretical background of this research, a number of parameters were chosen in order to apply on the case studies for thermal simulation. The following are the parameters that would be studied in comparison with the base case:

1) Window area ratio:

Three assumptions will be made considering the window area of the building's main facade, one is studying a **20 percent** window to wall area ratio, the second is studying a **40 percent** window to wall area ratio, and the third is studying a **100 percent** window to wall area ratio. The results will be compared with the base case results and also with each other. All secondary-façade windows will remain **constant** in window-to-wall area ratio assumptions, similar to the actual case design, which ranges from 5-10 percent window-to-wall area ratio.

2) Shading devices:

In addition to the 10cm shading that is given from the depth of the window, **70cm fixed overhangs** (horizontal shading) and **50cm fixed side fins** (vertical shading) would be added, and the results would be studied to see the effect on the energy consumption in cooling, as well as heating annually.

Note: Some other types of Shading were simulated at first in one example case, such as louvers in addition to the horizontal overhangs and vertical side fins. However. Because of the high number of modeled elements when adding the louvers, it took more than 90 minutes to simulate a single case. Therefore, only simple shading would be simulated.

3) Roof and Wall Insulation:

The base case design for all four buildings does not include any insulation, in either walls or roofs. The approximate wall U-value for a non-insulated wall is **1.82 w/m^2.K** and **2.66 w/m^2.K** for non-insulated roofs.

Two alternative insulation related options would be tested and simulated, one is the option of adopting the Energy Efficient Building code of Jordan minimum requirements of using **0.57 w/m^2.K** U-value at least for walls and **0.55 w/m^2.K** U-value at least for Roofs. This requires an addition of an approximately 3.3cm thick thermal insulation material in external walls and 5cm thick in external roofs.

See figure (18) and tables (29) and (30) for external wall properties, and figure (19) and tables (31) and (32) for external roof properties.

Table 29: Energy Efficient Building Code Requirements for External Walls, Components. (DesignBuilder®, 2009)

Layer	Name	Thickness (mm)	k-Value W/m.k	Sp. Heat J/kg.k	Density Kg/m^3
1	Jordan Stone	70	2.271	880	2600
2	Cast Concrete	180	1.130	1000	2000
3	Expanded Polystyrene	33	0.040	1400	15
4	Conc. Block (Hollow)	100	0.62	800	1700
5	Cement Plastering	20	0.88	896	2800

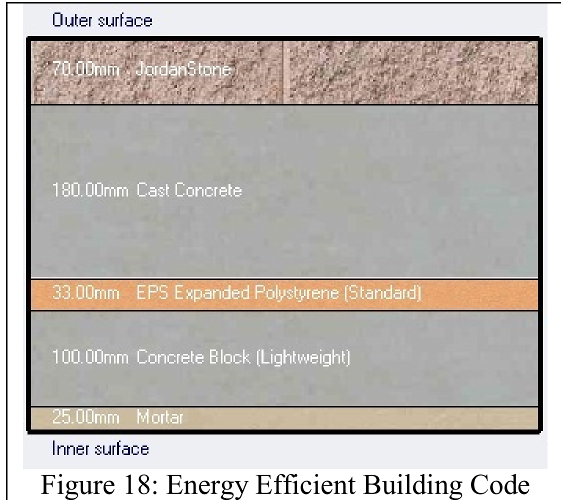


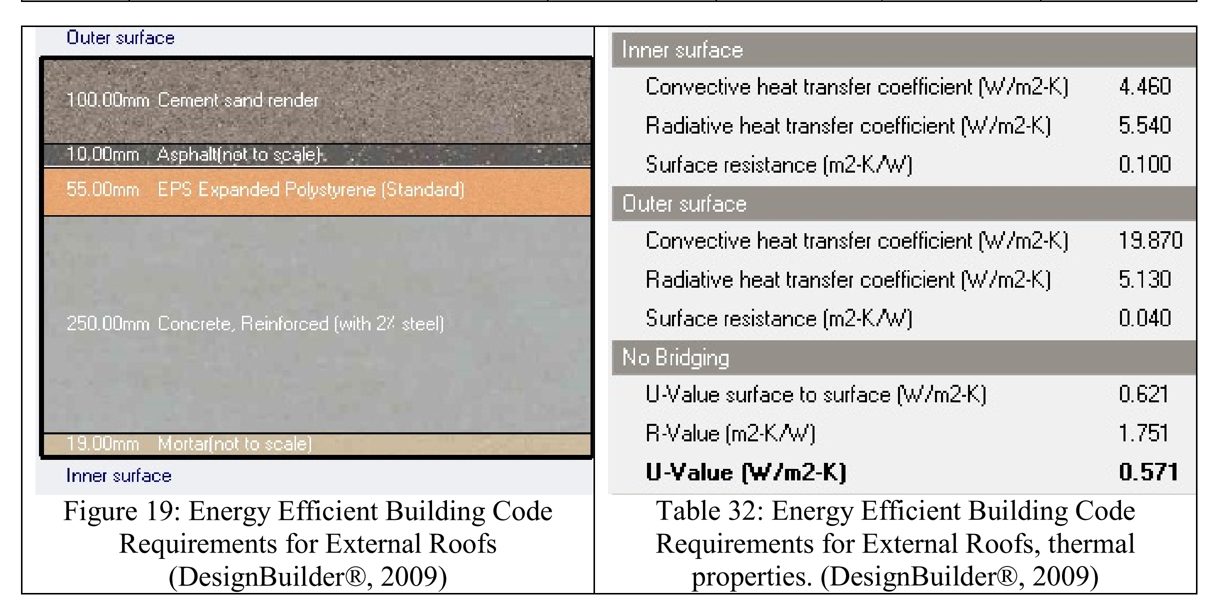
Figure 18: Energy Efficient Building Code Requirements for External Walls (DesignBuilder®, 2009)

Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.637
R-Value (m2-K/W)	1.740
U-Value (W/m2-K)	**0.575**

Table 30: Energy Efficient Building Code Requirements for External Walls, thermal properties (DesignBuilder®, 2009)

Table 31: Energy Efficient Building Code Requirements for External Roofs, Components. (DesignBuilder®, 2009)

Layer	Name	Thickness (mm)	k-Value W/m.k	Sp. Heat J/kg.k	Density Kg/m^3
1	Aggregates	100	1	1000	1800
2	Asphalt	10	0.7	1000	2100
3	Expanded Polystyrene	55	0.040	1400	15
4	Reinforced Concrete	250	2.5	1000	2400
5	Cement Plastering	19	0.88	896	2800



Inner surface	
Convective heat transfer coefficient (W/m2-K)	4.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.100
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.621
R-Value (m2-K/W)	1.751
U-Value (W/m2-K)	**0.571**

Figure 19: Energy Efficient Building Code Requirements for External Roofs (DesignBuilder®, 2009)

Table 32: Energy Efficient Building Code Requirements for External Roofs, thermal properties. (DesignBuilder®, 2009)

The other option is the use of a voluntary U-value requirement from the Green Building Guideline of Jordan**, 0.45 w/m^2.K** U-value for external walls and roofs. This requires an addition of an approximately 5.5cm thick thermal insulation material in external walls and 8cm thick in external roofs.

See figure (20) and tables (33) and (34) for external wall properties, and figure (21) and tables (35) and (36) for external roof properties.

Table 33: Green Building Guideline requirements, External Wall components (DesignBuilder®, 2009)

Layer	Name	Thickness (mm)	k-Value W/m.k	Sp. Heat J/kg.k	Density Kg/m^3
1	Jordan Stone	70	2.271	880	2600
2	Cast Concrete	180	1.130	1000	2000
3	Expanded Polystyrene	55	0.040	1400	15
4	Conc. Block (Hollow)	100	0.62	800	1700
5	Cement Plastering	20	0.88	896	2800

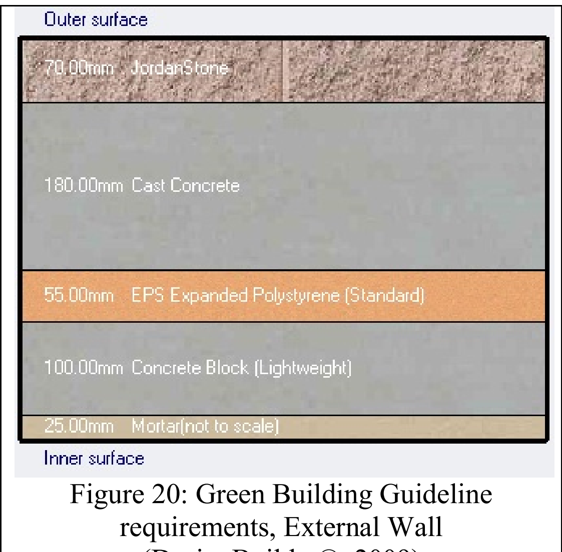


Figure 20: Green Building Guideline requirements, External Wall (DesignBuilder®, 2009)

Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.472
R-Value (m2-K/W)	2.290
U-Value (W/m2-K)	**0.437**

Table 34: Green Building Guideline requirements, External Wall thermal properties (DesignBuilder®, 2009)

Table 35: Green Building Guideline requirements, External Roof components. (DesignBuilder®, 2009)

Layer	**Name**	**Thickness (mm)**	**k-Value W/m.k**	**Sp. Heat J/kg.k**	**Density Kg/m^3**
1	Aggregates	100	1	1000	1800
2	Asphalt	10	0.7	1000	2100
3	Expanded Polystrene	80	0.040	1400	15
4	Reinforced Concrete	250	2.5	1000	2400
5	Cement Plastering	19	0.88	896	2800

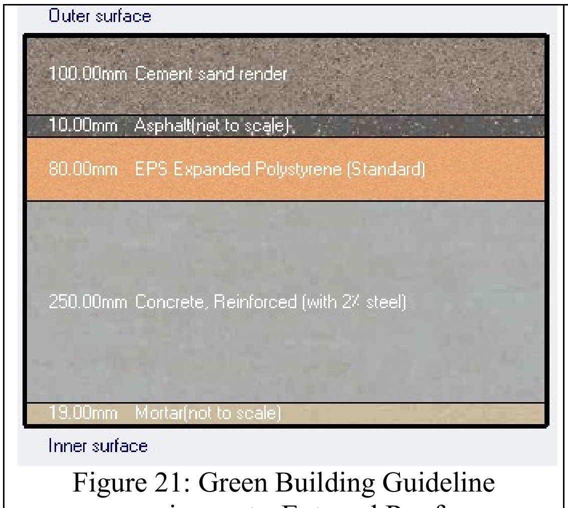


Figure 21: Green Building Guideline requirements, External Roof. (DesignBuilder®, 2009)

Inner surface	
Convective heat transfer coefficient (W/m2-K)	4.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.100
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.447
R-Value (m2-K/W)	2.376
U-Value (W/m2-K)	**0.421**

Table 36: Green Building Guideline requirements, External Roof thermal Properties. (DesignBuilder®, 2009)

4) Window Panes:

Single colored glazing is used in windows for all actual cases in the four buildings. **Four** alternative options of window pane properties would be studied and compared with the base case and each other in order to determine the most energy saving type for each building. These 4 options are:

a. Single clear glazing, U-value= **6.121 $W/m^2.K$** , see table (37).

b. Double clear glazing, U-value= **2.708 $W/m^2.K$** , see table (38).

c. Single Low-E glazing, U-value= **4.233 $W/m^2.K$** , see table (39).

d. Double Low-E glazing, U-value= **1.949 $W/m^2.K$** , see table (40).

Calculated Values	
Total solar transmission (SHGC)	0.810
Direct solar transmission	0.775
Light transmission	0.881
U-Value (W/m2-K)	**6.121**

Table 37: Single clear glazing (DesignBuilder®, 2009)

Calculated Values	
Total solar transmission (SHGC)	0.697
Direct solar transmission	0.604
Light transmission	0.781
U-Value (W/m2-K)	**2.708**

Table 38: Double clear glazing (DesignBuilder®, 2009)

Calculated Values	
Total solar transmission (SHGC)	0.710
Direct solar transmission	0.680
Light transmission	0.811
U-Value (W/m2-K)	**4.233**

Table 39: Single Low-E glazing (DesignBuilder®, 2009)

Calculated Values	
Total solar transmission (SHGC)	0.629
Direct solar transmission	0.531
Light transmission	0.721
U-Value (W/m2-K)	**1.949**

Table 40: Double Low-E glazing (DesignBuilder®, 2009)

These options will be allocated for all windows in the building, including main facade windows and other secondary façade windows.

5) **Optimized Cases:**

The parameters from 1 to 4 above will be examined and the results would be analyzed to create optimum cases based on heating and cooling requirements.

Therefore, in order to reach all possible merging of the parameters, each case study of the four buildings will be represented in 72 cases in addition to the base case and optimum case. In total, 4 base cases, 288 parameter studies and 4 optimum cases. Tables (41), (42) and (43) summarize possible parameter combinations for case studies.

Table 41: parameters for case study No. 1- with windows on 20% of main façade. (Author)

Case No.**	**Window size %**	**No. of pane**	**Window Glass**	**U-value**	**Shading**	**Name***
Base						
1	20	1	Clear	1.6	None	20%1C1None
2	20	2	Clear	1.6	None	20%2C1None
3	20	1	Low-E	1.6	None	20%1E1None
4	20	2	Low-E	1.6	None	20%2E1None
5	20	1	Clear	0.57	None	20%1C2None
6	20	2	Clear	0.57	None	20%2C2None
7	20	1	Low-E	0.57	None	20%1E2None
8	20	2	Low-E	0.57	None	20%2E2None
9	20	1	Clear	0.45	None	20%1C3None
10	20	2	Clear	0.45	None	20%2C3None
11	20	1	Low-E	0.45	None	20%1E3None
12	20	2	Low-E	0.45	None	20%2E3None
13	20	1	clear	1.6	Shading	20%1C1Shading
14	20	2	clear	1.6	Shading	20%2C1Shading
15	20	1	Low-E	1.6	Shading	20%1E1Shading
16	20	2	Low-E	1.6	Shading	20%2E1Shading
17	20	1	clear	0.57	Shading	20%1C2Shading
18	20	2	clear	0.57	Shading	20%2C2Shading
19	20	1	Low-E	0.57	Shading	20%1E2Shading
20	20	2	Low-E	0.57	Shading	20%2E2Shading
21	20	1	clear	0.45	Shading	20%1C3Shading
22	20	2	clear	0.45	Shading	20%2C3Shading
23	20	1	Low-E	0.45	Shading	20%1E3Shading
24	20	2	Low-E	0.45	Shading	20%2E3Shading

*Note *:* *See end of Table (43)*
*Note **:* *See end of Table (43)*

Table 42: parameters for case study No. 1- with windows on 40% of main façade. (Author)

Case No.**	**Window size %**	**No. of pane**	**Window Glass**	**U-value**	**Shading**	**Name***
25	40	1	clear	1.6	None	40%1C1None
26	40	2	clear	1.6	None	40%2C1None
27	40	1	Low-E	1.6	None	40%1E1None
28	40	2	Low-E	1.6	None	40%2E1None
29	40	1	clear	0.57	None	40%1C2None
30	40	2	clear	0.57	None	40%2C2None
31	40	1	Low-E	0.57	None	40%1E2None
32	40	2	Low-E	0.57	None	40%2E2None
33	40	1	clear	0.45	None	40%1C3None
34	40	2	clear	0.45	None	40%2C3None
35	40	1	Low-E	0.45	None	40%1E3None
36	40	2	Low-E	0.45	None	40%2E3None
37	40	1	clear	1.6	Shading	40%1C1Shading
38	40	2	clear	1.6	Shading	40%2C1Shading
39	40	1	Low-E	1.6	Shading	40%1E1Shading
40	40	2	Low-E	1.6	Shading	40%2E1Shading
41	40	1	clear	0.57	Shading	40%1C2Shading
42	40	2	clear	0.57	Shading	40%2C2Shading
43	40	1	Low-E	0.57	Shading	40%1E2Shading
44	40	2	Low-E	0.57	Shading	40%2E2Shading
45	40	1	clear	0.45	Shading	40%1C3Shading
46	40	2	clear	0.45	Shading	40%2C3Shading
47	40	1	Low-E	0.45	Shading	40%1E3Shading
48	40	2	Low-E	0.45	Shading	40%2E3Shading

*Note *:* *See end of Table (43)*
*Note **:* *See end of Table (43)*

Table 43: Parameters for case studies- with windows on ≈100% of main façade. (Author)

Case	**Window**	**No. of**	**Window**	**U-value**	**Shading**	**Name***
49	100	1	clear	1.6	None	100%1C1None
50	100	2	clear	1.6	None	100%2C1None
51	100	1	Low-E	1.6	None	100%1E1None
52	100	2	Low-E	1.6	None	100%2E1None
53	100	1	clear	0.57	None	100%1C2None
54	100	2	clear	0.57	None	100%2C2None
55	100	1	Low-E	0.57	None	100%1E2None
56	100	2	Low-E	0.57	None	100%2E2None
57	100	1	clear	0.45	None	100%1C3None
58	100	2	clear	0.45	None	100%2C3None
59	100	1	Low-E	0.45	None	100%1E3None
60	100	2	Low-E	0.45	None	100%2E3None
61	100	1	clear	1.6	Shading	100%1C1 Shading
62	100	2	clear	1.6	Shading	100%2C1 Shading
63	100	1	Low-E	1.6	Shading	100%1E1 Shading
64	100	2	Low-E	1.6	Shading	100%2E1 Shading
65	100	1	clear	0.57	Shading	100%1C2 Shading
66	100	2	clear	0.57	Shading	100%2C2 Shading
67	100	1	Low-E	0.57	Shading	100%1E2 Shading
68	100	2	Low-E	0.57	Shading	100%2E2 Shading
69	100	1	clear	0.45	Shading	100%1C3 Shading
70	100	2	clear	0.45	Shading	100%2C3 Shading
71	100	1	Low-E	0.45	Shading	100%1E3 Shading
72	100	2	Low-E	0.45	Shading	100%2E3 Shading

*Note *:* *See Following page*
*Note **:* *See Following page*

Note:* *The name of the parametric case is derived, to easily identify each case parameters. The name is combined from table (44) for suggestions in consequence.*

Table 44: name code suggestions (Author)

Size (window to wall ratio) %	No. of Panes for windows	Glass Properties	U-value of walls and roofs ($kWh/m^2.C$)	Shading Availability
20%	Single=1	Clear=C	(No Insulation 1.15)=1	None
40%	Double=2	Low-e=E	(Insulation 0.57)=2	Shading
100%			(Insulation 0.45)=3	Adjustable

For example, a case where the areas of the windows on the main façade are ***40%*** *of the wall area, with* ***double*** *glazing, and* ***Low-e*** *coating, along with minimum insulation requirements (**0.57 $kWh/m^2.C$** for the U-value) in walls and roofs and,* ***shading*** *only on the main façade; this case will acquire the name:* ***40%2E2Shading***

*Note**:* *Although more parameters and combination are possible, only these relatively minimum parameters where chose to simulate using DesignBuilder®. This is due to the relatively large amount of time DesignBuilder® Software consumes in simulating each case, which is around one-half an hour each.*

3-3-11 Simulation Process

Computer simulation were used in order to conclude the optimum way to provide a thermally comfortable environment with minimum energy demand inside the building, and to find the best case that has the lowest energy consumption for cooling in summer and heating in winter.

In the beginning of the simulation process, the title of the project allocated in DesignBuilder®, along with general description files, such as the location and country of existence, in order to connect the project with the weather data associated with the location.

The four case study buildings were first simulated according to their actual design parameters, i.e. same form, fenestration layout and material uses. “Base case” results were obtained.

According to the method of the study, different cases were created to test the assumptions mentioned in paragraph 3-3-10, the main goal was to find the most energy saving assumption compared with the amount of energy consumption generated by the base case results.

By using the base case model and copying it, parameters mentioned in tables (41) to (43) were adapted in new copied cases and simulated again according to that change, in order to generate new energy consumption results to compare with the base case and other cases. Each case would take between 30 and 55 minutes to run the results.

3-4 Building One (South-West Orientation)

3-4-1 Location:

Building One is located on Wasfi Attal Street, city of Amman, where the main façade is oriented to the South- West. See figure (22).

3-4-2 Design:

The building consists of a retail-shop functioned ground floor, a mezzanine floor, and three typical- plan stories holding offices. See photo (1) for an actual image of the building, and figure (23) for a modeled image of the building.

Based on the original plans and elevations, obtained from management crew of the building, the building’s typical floor layout was modeled as shown in figure (24), with an approximate area of **(475.00) m^2/floor**, 2375 m^2 in total



Figure 22: Building One, South-West Orientation, Wasfi Attal St. (GoogleEarth®, 2011)



Photo 1: Actual image of Building One, taken in Feb 2011

The main façade, which is oriented to the South-West Orientation, consists of blue colored glazing and Aloca-bond material as a frame. The rest of the building has rough plastering material, with light color and a limited number of openings.

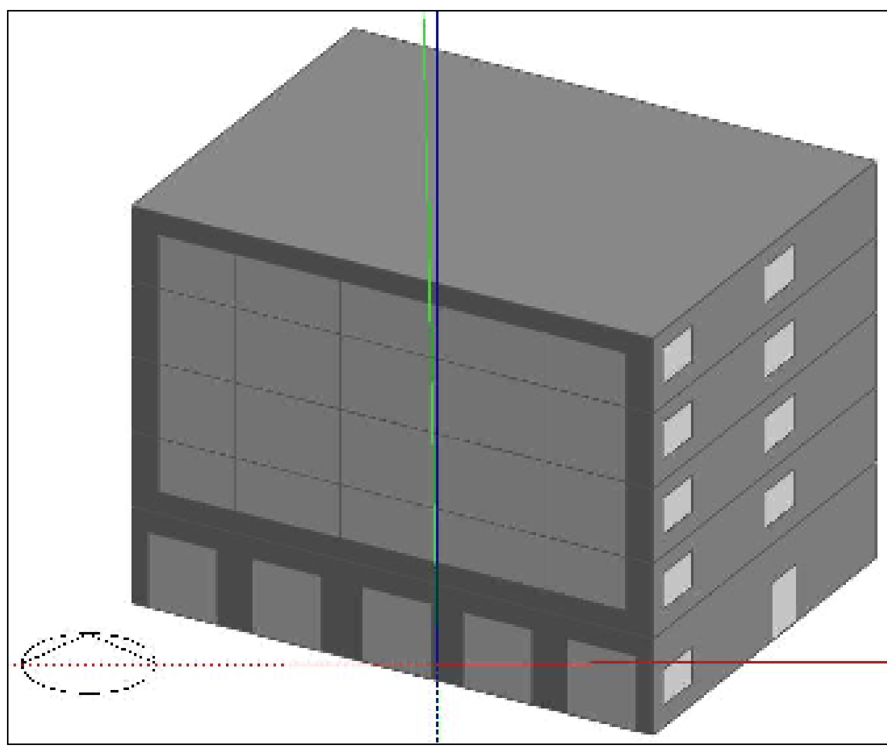


Figure 23: Modeled image of Building One. (Author)

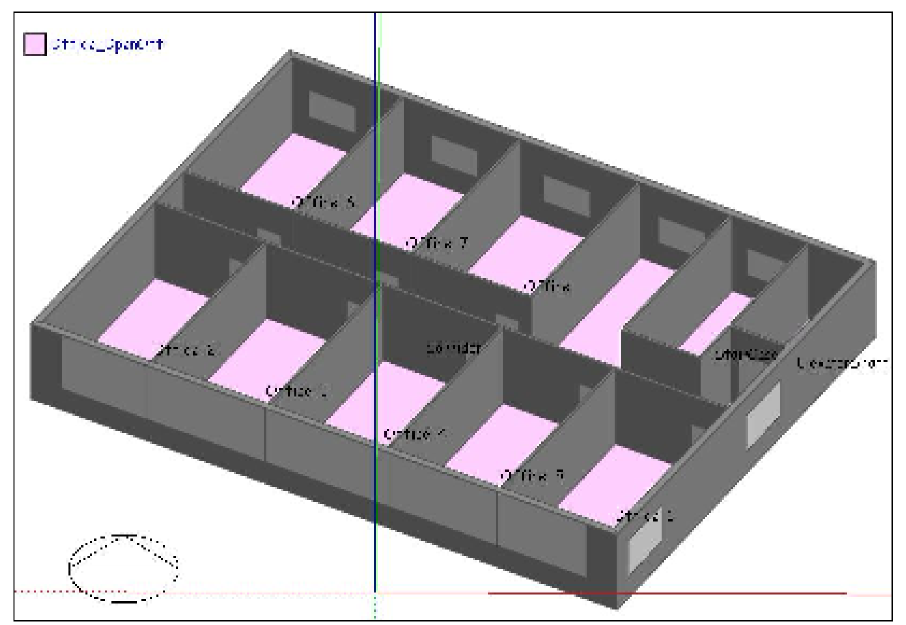


Figure 24: Typical floor layout of Building One (Author)

3-4-3 Base Case Simulation:

Base case Results for annual heating and cooling requirements are shown in table (45). The results are normalized per meter square of area, NOT as total energy consumption for the whole building. This is due to the importance of establishing a benchmark energy consumption for infill-commercial buildings in Jordan.

Table 45: Base Case, Building One Results (Author)

Name	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2
Base Case Building One SW	61.6183	163.128	224.7464

3-4-4 Parametric Cases Simulation:

It was unable to judge the energy consumption levels based on this result alone, because of the lack of benchmark energy consumption data of office buildings in Jordan. However, performing parametric simulations on the same building will provide comparison chances, and energy performance indicators could be delivered. Figures (25), (26) and (27) show the parametric cases of 20 percent WWR, 40 percent WWR and 100 percent WWR, respectively, without any shading. On the other hand, figures (28), (29) and (30) show the parametric cases of 20 percent WWR, 40 percent WWR and 100 percent WWR, respectively, with shading.

Table (46) shows the annual heating and cooling demand. The results were normalized per meter square of area, in order to compare the result with the base case results. Cases are color coded in table (12-31) to represent the following:

1) Cases in Red represent cases with the lowest energy demand needed for heating.
2) Cases in Orange represent cases with the highest energy demand needed for heating.
3) Cases in Dark blue represent cases with the lowest energy demand needed for cooling.
4) Cases in Light blue represent cases with the highest energy demand needed for cooling.
5) Cases in Green represent cases with the lowest total energy demand.
6) Cases in yellow represent cases with the highest total energy demand.

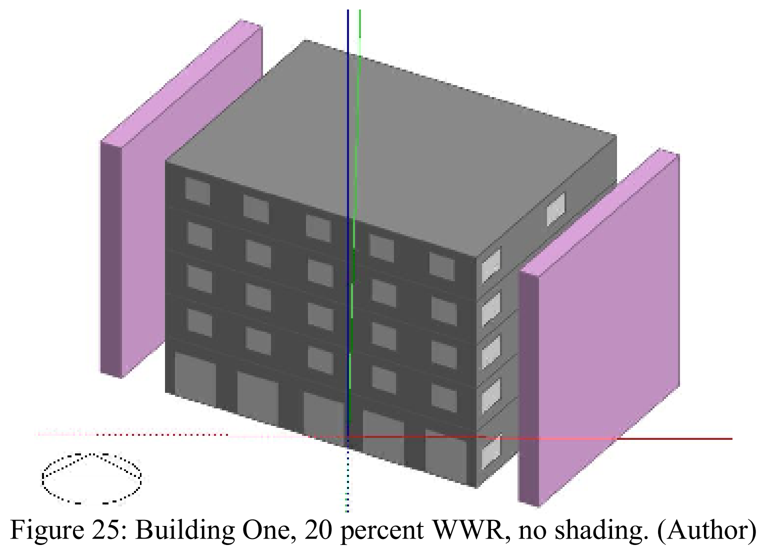


Figure 25: Building One, 20 percent WWR, no shading. (Author)

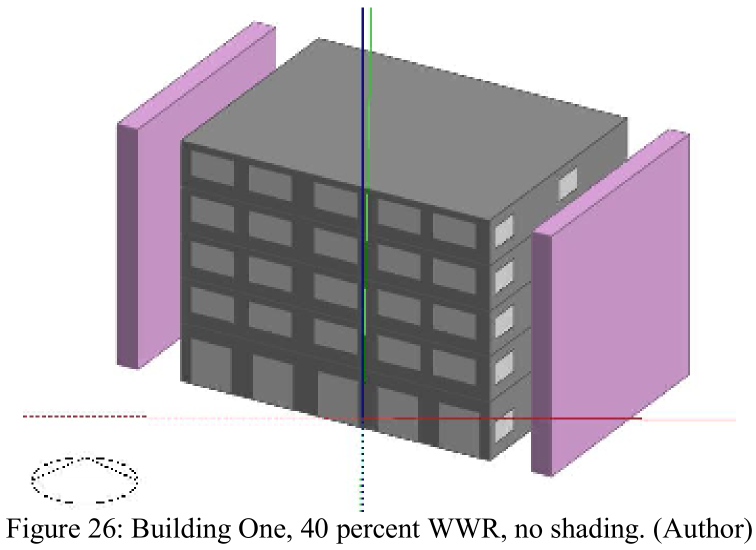


Figure 26: Building One, 40 percent WWR, no shading. (Author)

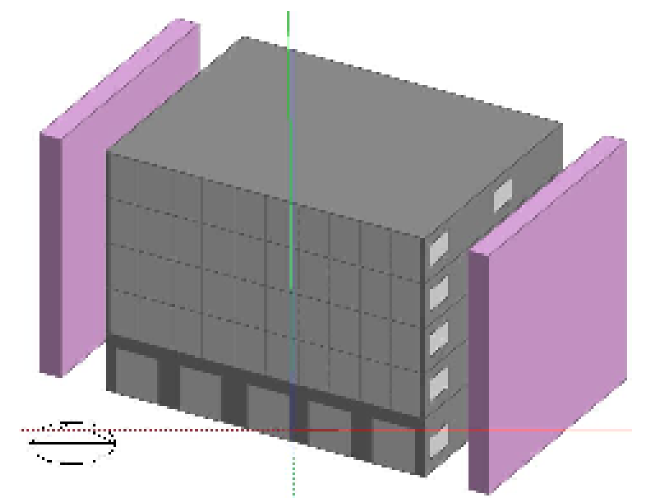


Figure 27: Building One, 100 percent WWR, no shading (Author)

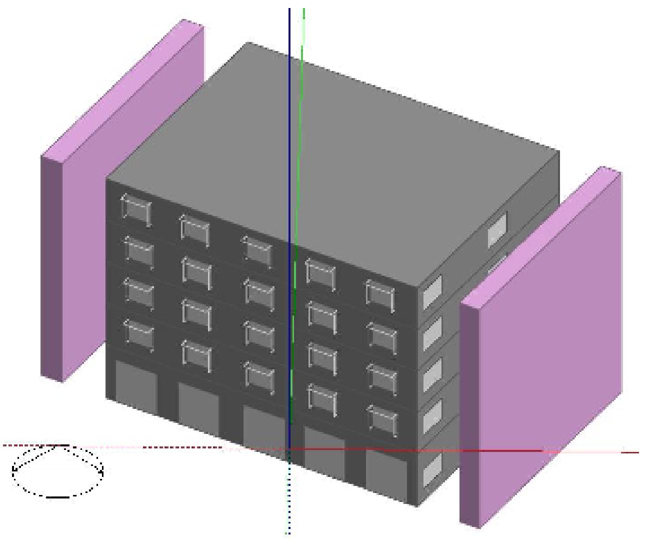


Figure 28: Building One, 20 percent WWR, with shading. (Author)

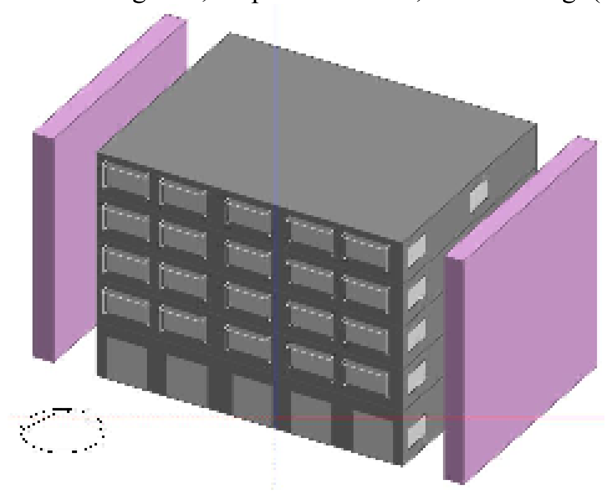


Figure 29: Building One, 40 percent WWR, with shading. (Author)

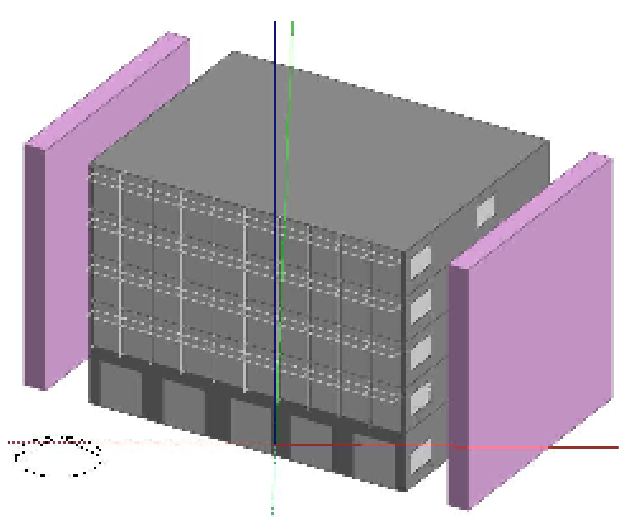


Figure 30: Building One, 100 percent WWR, with shading. (Author)

Table 46: Parametric Cases annual results for Building One, SW Orientation. (Author)

Building	One	South West Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
20	1C1	OFF	69.40177	147.9375	217.3393	ON	74.0112	145.0357	219.0469
20	1C2	OFF	41.05675	154.4789	195.5357	ON	55.04277	148.3023	203.3451
20	1C3	OFF	42.46468	155.3261	197.7908	ON	51.56503	149.5457	201.1107
20	1E1	OFF	62.22967	151.664	213.8937	ON	70.46877	148.3314	218.8001
20	1E2	OFF	42.56179	156.6989	199.2606	ON	51.10208	152.3276	203.4297
20	1E3	OFF	38.91166	158.3314	197.2431	ON	47.52328	153.7689	201.2921
20	2C1	OFF	61.46713	150.9112	212.3783	ON	69.31608	148.3895	217.7056
20	2C2	OFF	41.99458	155.6347	197.6293	ON	50.12593	152.2223	202.3482
20	2C3	OFF	38.38916	157.1978	195.587	ON	46.59205	153.6287	200.2207
20	2E1	OFF	60.05241	151.9162	211.9686	ON	67.46721	150.199	217.6662
20	2E2	OFF	41.05675	154.4789	195.5357	ON	48.18365	154.33	202.5137
20	2E3	OFF	36.81446	158.4463	195.2608	ON	44.62602	155.8137	200.4397

Building	One	South West Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
40	1C1	OFF	65.6773	164.4391	230.11635	ON	76.35271	141.7112	218.06388
40	1C2	OFF	47.8065	170.3983	218.20482	ON	58.21919	144.5895	202.80873
40	1C3	OFF	44.6158	172.126	216.74183	ON	54.96494	145.7064	200.67133
40	1E1	OFF	61.5196	167.3712	228.89085	ON	71.1484	145.939	217.08743
40	1E2	OFF	42.9401	174.452	217.39216	ON	52.30949	149.8632	202.17265
40	1E3	OFF	39.572	176.4641	216.03617	ON	48.89542	151.2494	200.14478
40	2C1	OFF	60.9656	164.276	225.2416	ON	69.50171	145.6345	215.13626
40	2C2	OFF	42.7447	170.5378	213.28246	ON	50.98643	149.2654	200.25186
40	2C3	OFF	39.4592	172.3706	211.82983	ON	47.6446	150.5865	198.2311
40	2E1	OFF	59.2792	164.7835	224.06267	ON	67.04541	147.5485	214.59396
40	2E2	OFF	40.8744	171.2866	212.161	ON	48.35963	151.559	199.91868
40	2E3	OFF	37.5428	173.2009	210.74371	ON	44.97328	152.976	197.94926

Building	One	South West Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
100	1C1	OFF	58.85735	197.7868	256.6442	ON	74.66824	152.9415	227.6097
100	1C2	OFF	43.69535	205.4329	249.1282	ON	58.55123	156.3094	214.8606
100	1C3	OFF	41.16252	207.2256	248.3881	ON	55.86919	157.3767	213.2459
100	1E1	OFF	50.97773	207.5349	258.5126	ON	64.96618	161.3937	226.3599
100	1E2	OFF	35.22325	218.2178	253.441	ON	48.07242	166.6261	214.6985
100	1E3	OFF	32.58844	220.6209	253.2093	ON	45.22026	168.084	213.3043
100	2C1	OFF	51.05517	198.7652	249.8204	ON	63.2572	159.6368	222.894
100	2C2	OFF	35.72004	207.67	243.39	ON	46.97488	164.1689	211.1437
100	2C3	OFF	33.1553	209.7574	242.9127	ON	44.22947	165.4966	209.726
100	2E1	OFF	48.28497	199.9353	248.2203	ON	59.36734	162.3241	221.6914
100	2E2	OFF	32.842	209.6036	242.4456	ON	42.8835	167.4786	210.3621
100	2E3	OFF	30.26909	211.8645	242.1336	ON	40.09144	168.9457	209.0372

3-5 Building Two (South-East Orientation)

3-5-1 Location:

Building Two is located on Madina Al-Monawwara Street, city of Amman, where the main façade is oriented to the South- East. See figure (31).

3-5-2 Design:

The building consists of a retail-shop functioned ground floor, a mezzanine floor, and five typical- plan stories holding offices. See photo (2) for an actual image of the building, and figure (32) for a modeled image of the building.

Based on the original plans and elevations, obtained from management crew of the building, the building's typical floor layout was modeled as shown in figure (32), with an approximate area of **(464) m^2/floor,** 3248 m^2 in total.

The main façade, which is oriented to the South-East Orientation, consists of bronze colored glazing and stone cladding material in external walls. The rest of the building has rough plastering material, with light color and a limited number of openings.

3-5-3 Base Case Simulation:

Base case Results for annual heating and cooling requirements are shown in table (47). The results are normalized per meter square of area.

Table 47: Base case results, building Two. (Author)

Name	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2
Base Case Building Two SE	57.7068	171.121	228.8276



Figure 31: Building Two, South-East Orientation, Madina St. (GoogleEarth®, 2011)



Photo 2: Actual image of Building Two, taken in Feb 2011

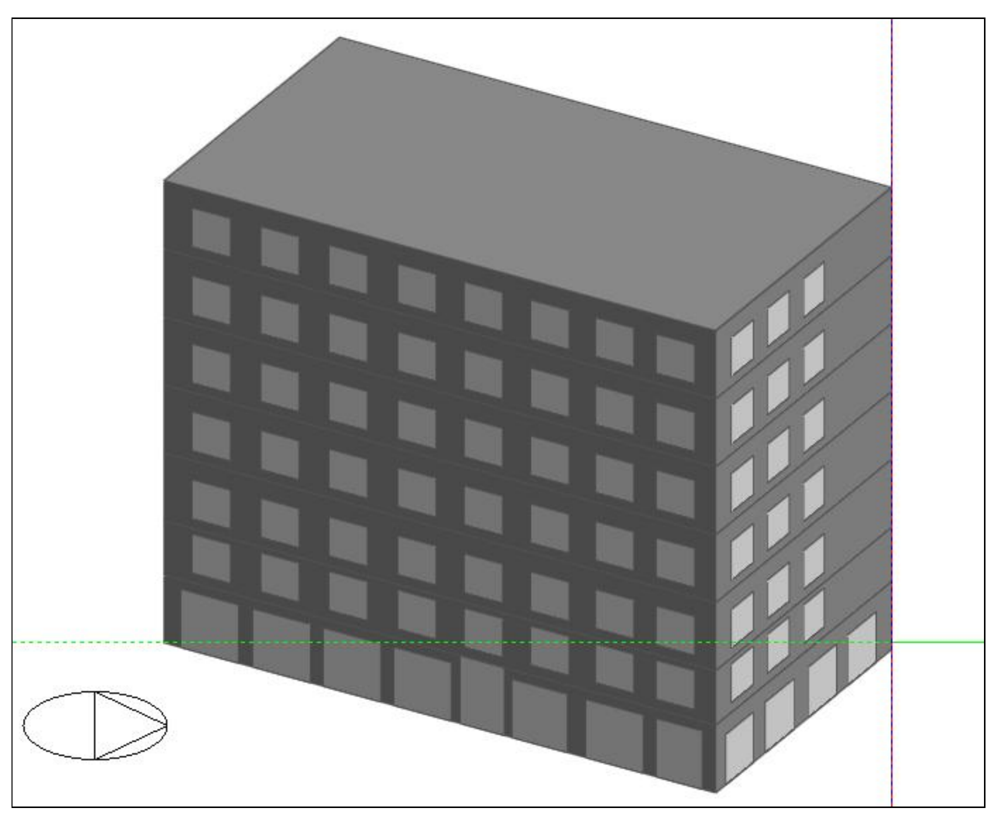


Figure 32: Modeled image of Building Two (Author)

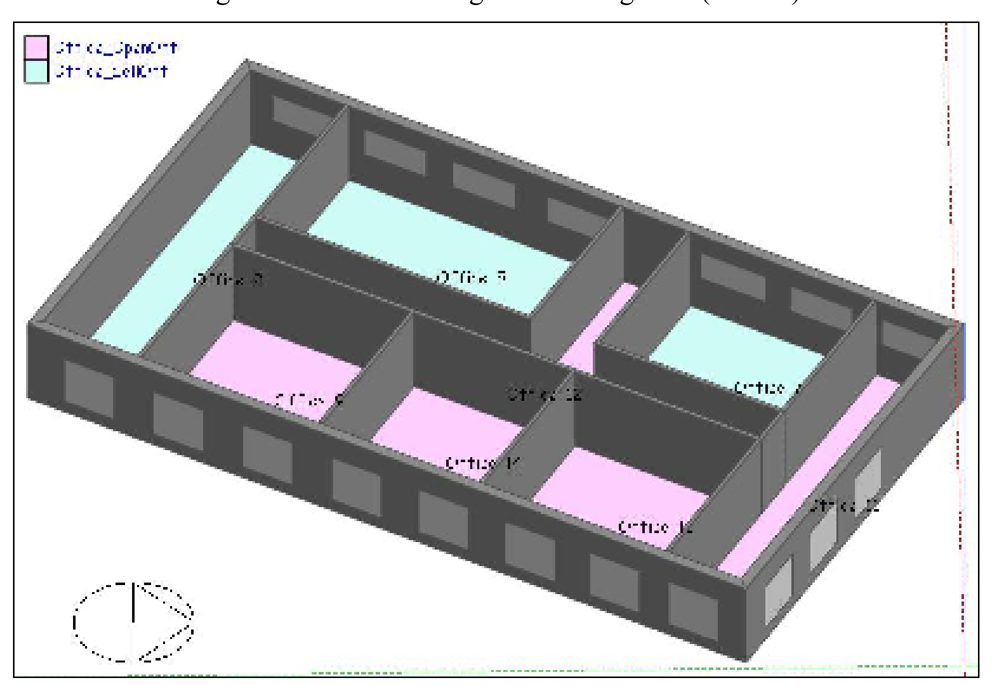


Figure 33: Typical floor layout of Building Two (Author)

3-5-4 Parametric Cases Simulation:

Figures (34), (35) and (36) show the parametric cases of 20 percent WWR, 40 percent WWR and 100 percent WWR, respectively, without any shading. On the other hand, figures (37), (38) and (39) show the parametric cases of 20 percent WWR, 40 percent WWR and 100 percent WWR, respectively, with shading.

Table (48) shows the annual heating and cooling demand. The results were normalized per meter square of area, in order to compare the result with the base case results.

Cases are color coded in table (48) to represent the following:

1) Cases in Red represent cases with the lowest energy demand needed for heating.
2) Cases in Orange represent cases with the highest energy demand needed for heating.
3) Cases in Dark blue represent cases with the lowest energy demand needed for cooling.
4) Cases in Light blue represent cases with the highest energy demand needed for cooling.
5) Cases in Green represent cases with the lowest total heating and cooling energy demand.
6) Cases in yellow represent cases with the highest total heating and cooling energy demand.

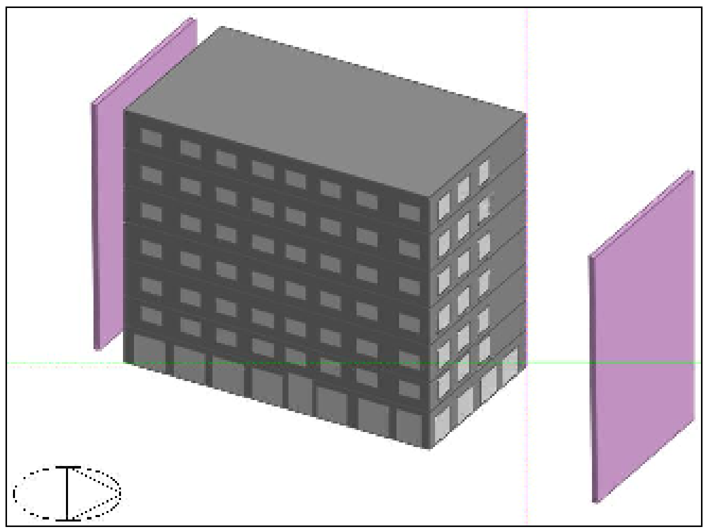


Figure 34: Building Two, 20 percent WWR, no shading (Author)

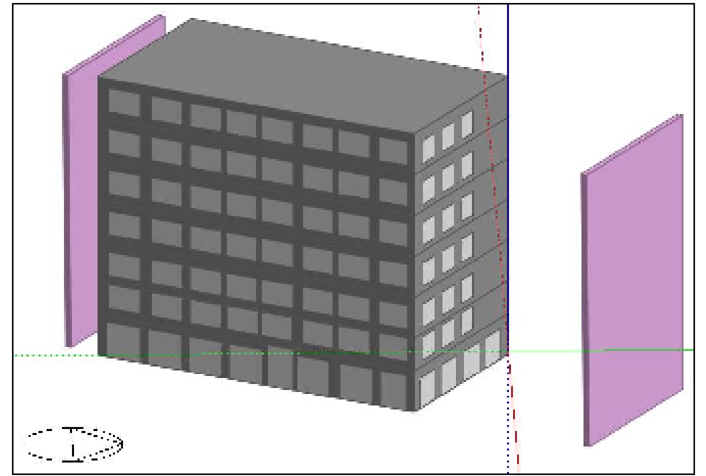


Figure 35: Building Two, 40 percent WWR, no shading (Author)

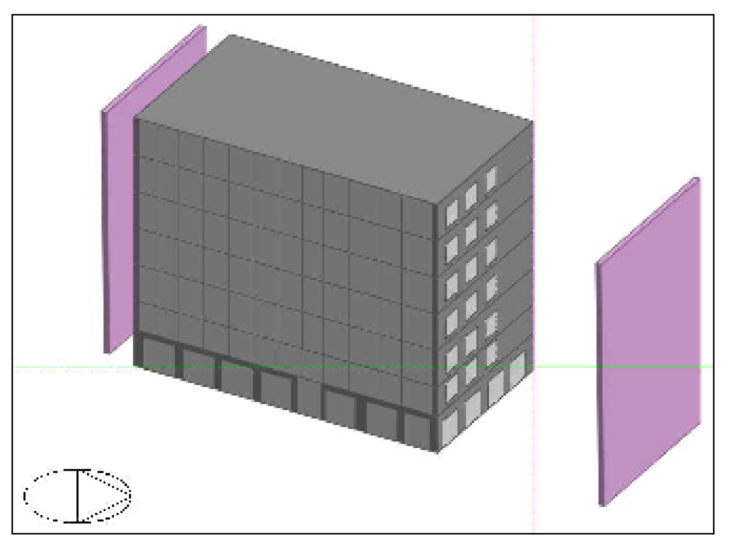


Figure 36: Building Two, 100 percent WWR, no shading (Author)

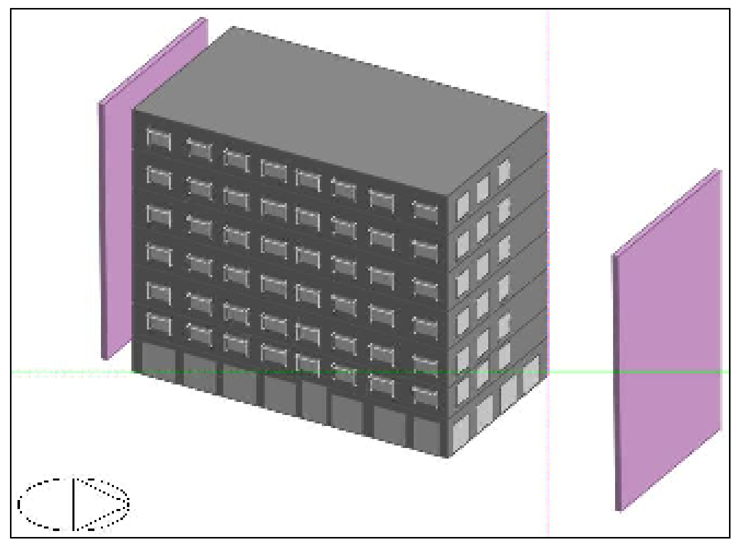


Figure 37: Building Two, 20 percent WWR, with shading (Author)

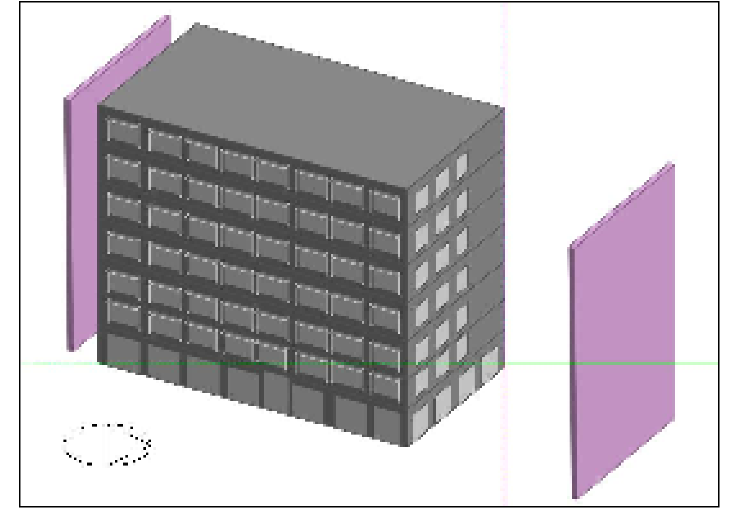


Figure 38: Building Two, 40 percent WWR, with shading (Author)

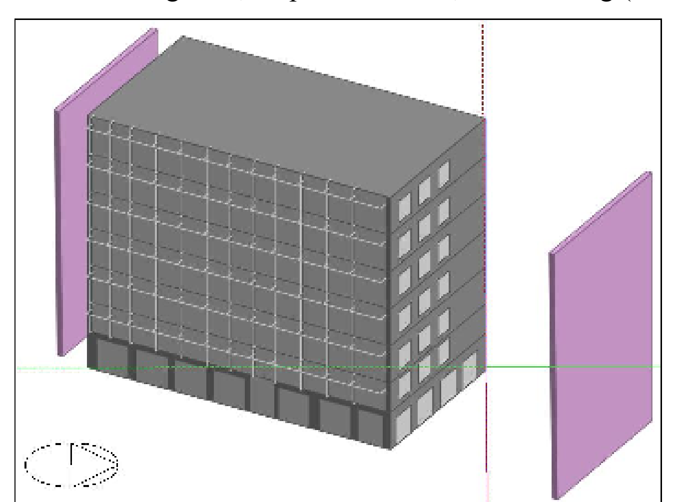


Figure 39: Building Two, 100 percent WWR, with shading (Author)

Table 48: Parametric Cases annual results for Building Two SE Orientation. (Author)

Building	Two	South East Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
20	1C1	OFF	49.50751	161.4083	210.9158	ON	71.2214	116.0136	187.235
20	1C2	OFF	36.06044	167.6967	203.7572	ON	56.91319	118.6124	175.5256
20	1C3	OFF	33.43638	169.4839	202.9203	ON	54.10392	119.524	173.6279
20	1E1	OFF	45.84699	163.8778	209.7248	ON	66.4991	118.9928	185.4919
20	1E2	OFF	31.83831	171.1298	202.9681	ON	51.65684	122.2958	173.9526
20	1E3	OFF	29.05935	173.1916	202.2509	ON	48.69931	123.4145	172.1139
20	2C1	OFF	44.93272	161.2285	206.1612	ON	64.87591	118.1045	182.9805
20	2C2	OFF	31.20212	167.9197	199.1218	ON	50.26793	121.1004	171.3683
20	2C3	OFF	28.49947	169.848	198.3475	ON	47.36782	122.1389	169.5067
20	2E1	OFF	43.34937	161.0337	204.3831	ON	47.36782	122.1389	169.5067
20	2E2	OFF	29.49924	167.9124	197.4117	ON	47.66217	122.56	170.2222
20	2E3	OFF	26.76071	169.9123	196.673	ON	44.71369	123.6792	168.3929

Building	Two	South East Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
40	1C1	OFF	47.3164	175.1792	222.49561	ON	65.85799	120.6511	186.50906
40	1C2	OFF	34.7936	182.2761	217.06967	ON	59.18447	120.7134	179.89789
40	1C3	OFF	32.4221	184.1687	216.59072	ON	56.6132	121.6105	178.22374
40	1E1	OFF	42.2647	179.5167	221.78137	ON	66.29074	122.0377	188.32842
40	1E2	OFF	29.1389	188.0537	217.19258	ON	52.10209	125.6579	177.76004
40	1E3	OFF	26.6069	190.3341	216.94101	ON	49.33932	126.8157	176.15507
40	2C1	OFF	41.4996	175.264	216.7636	ON	64.32798	120.8209	185.14887
40	2C2	OFF	28.693	182.9645	211.65751	ON	50.48059	124.0572	174.53783
40	2C3	OFF	26.2517	185.0547	211.30636	ON	47.79864	125.1221	172.92078
40	2E1	OFF	39.4645	175.0968	214.56127	ON	61.24205	122.1355	183.37757
40	2E2	OFF	26.5444	183.1215	209.66589	ON	47.16986	125.8624	173.03223
40	2E3	OFF	24.0725	185.3103	209.3828	ON	44.42178	127.0235	171.44532

Building	Two	South East Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
100	1C1	OFF	44.14182	201.4078	245.5496	ON	73.49135	127.7778	201.2692
100	1C2	OFF	33.45517	208.8828	242.3379	ON	61.67627	130.6994	192.3756
100	1C3	OFF	31.55208	210.6686	242.2207	ON	59.57377	131.5508	191.1245
100	1E1	OFF	36.42842	213.0126	249.4411	ON	63.34393	135.4863	198.8302
100	1E2	OFF	25.21985	223.0218	248.2416	ON	50.73264	139.7692	190.5018
100	1E3	OFF	23.17546	225.3755	248.551	ON	48.43515	140.9513	189.3864
100	2C1	OFF	36.00745	204.6152	240.6227	ON	61.05147	133.6299	194.6814
100	2C2	OFF	25.20346	213.2732	238.4767	ON	48.94479	137.3536	186.2984
100	2C3	OFF	23.25534	215.3487	238.6041	ON	46.75716	138.4103	185.1674
100	2E1	OFF	33.2462	205.9373	239.1835	ON	56.59068	135.7922	192.3829
100	2E2	OFF	22.43201	215.2438	237.6758	ON	44.28879	139.9421	184.2309
100	2E3	OFF	20.47608	217.4763	237.9523	ON	42.03178	141.1153	183.1471

3-6 Building Three (North-West Orientation)

3-6-1 Location:

Building Three is located on Madina Al-Monawwara Street, city of Amman, where the main façade is oriented to the North- West. See figure (40).

3-6-2 Design:

The building consists of a retail-shop functioned ground floor, a mezzanine floor, and five typical- plan stories holding offices. See photo (3) for an actual image of the building, and figure (41) for a modeled image of the building.

Based on the original plans and elevations, obtained from management crew of the building, the building's typical floor layout was modeled as shown in figure (42), with an approximate area of **(390) m^2/floor**, 2730 m^2 in total.

The main façade, which is oriented to the North-West Orientation, consist of grey colored glazing and some Stone strips on its external walls. The rest of the building has rough plastering material, with light color and a limited number of openings.

3-6-3 Base Case Simulation:

Base case Results for annual heating and cooling requirements are shown in table (49). The results are normalized per meter square of area.

Table 49: Base case results, Building Three. (Author)

Name	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2
Base Case Building Three NW	59.5813	147.099	206.6807



Figure 40: Building Three, North-West Orientation, Madina St. (GoogleEarth®, 2011)



Photo 3: Actual image of Building Three, taken in Feb 2011

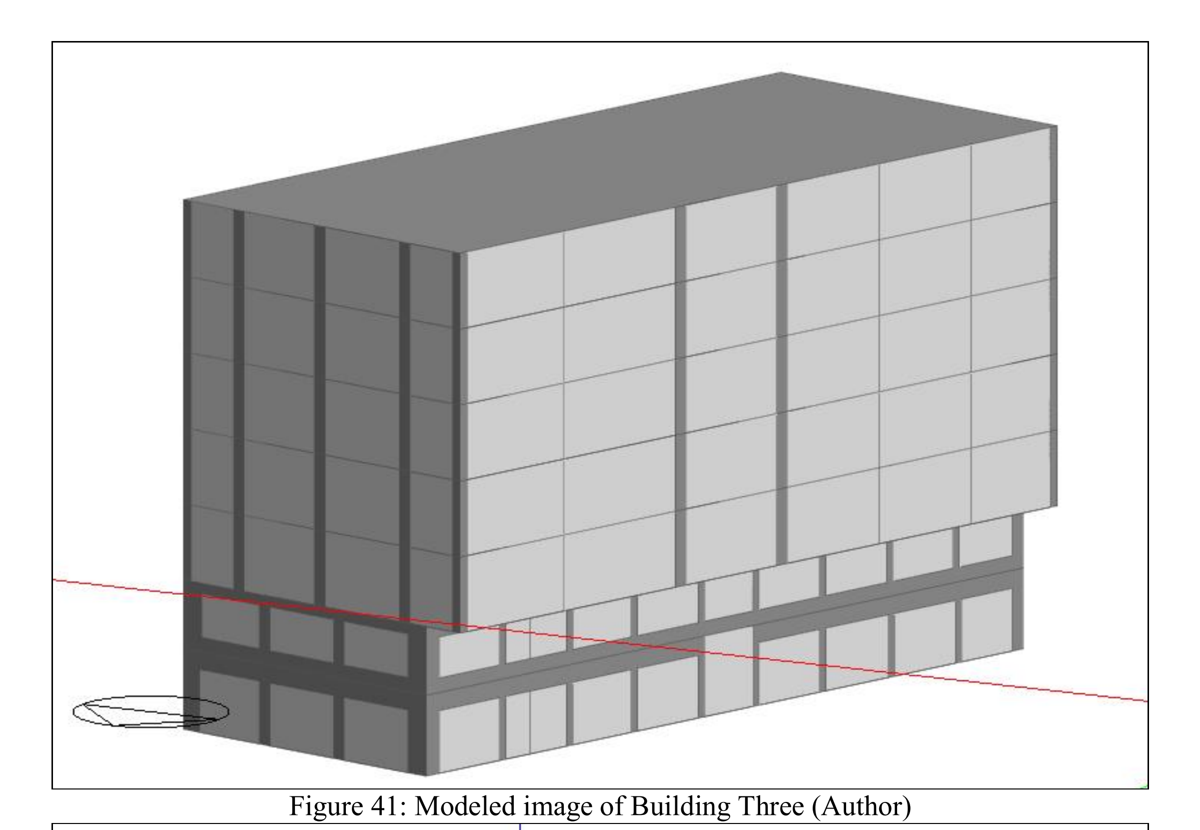


Figure 41: Modeled image of Building Three (Author)

Figure 42: Typical floor layout of Building Three (Author)

3-6-4 Parametric Cases Simulation:

Figures (43), (44) and (45) show the parametric cases of 20 percent WWR, 40 percent WWR and 100 percent WWR, respectively, without any shading. On the other hand, figures (46), (47) and (48) show the parametric cases of 20 percent WWR, 40 percent WWR and 100 percent WWR, respectively, with shading.

Table (50) shows the annual heating and cooling demand. The results were normalized per meter square of area, in order to compare the result with the base case results.

Cases are color coded in table (50) to represent the following:

1) Cases in Red represent cases with the lowest energy demand needed for heating.
2) Cases in Orange represent cases with the highest energy demand needed for heating.
3) Cases in Dark blue represent cases with the lowest energy demand needed for cooling.
4) Cases in Light blue represent cases with the highest energy demand needed for cooling.
5) Cases in Green represent cases with the lowest total heating and cooling energy demand.
6) Cases in yellow represent cases with the highest total heating and cooling energy demand.

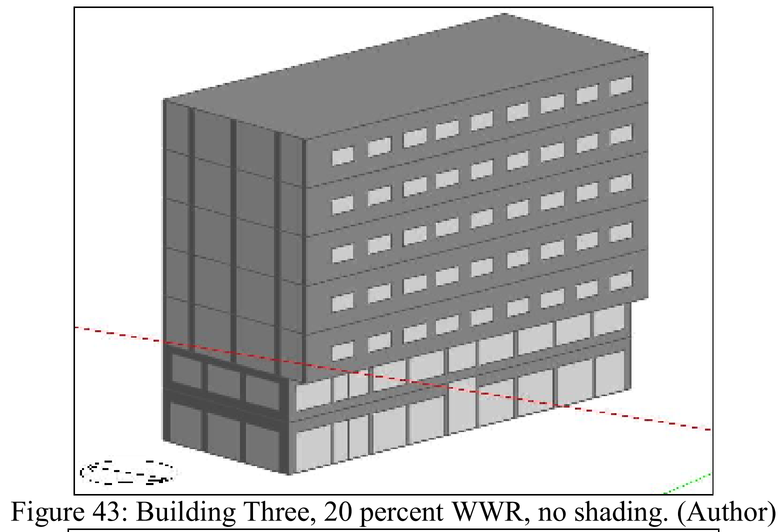


Figure 43: Building Three, 20 percent WWR, no shading. (Author)

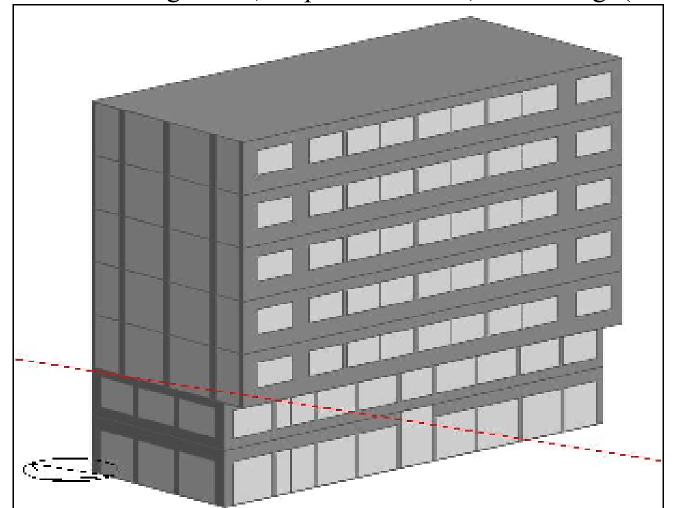


Figure 44: Building Three, 40 percent WWR, no shading (Author)

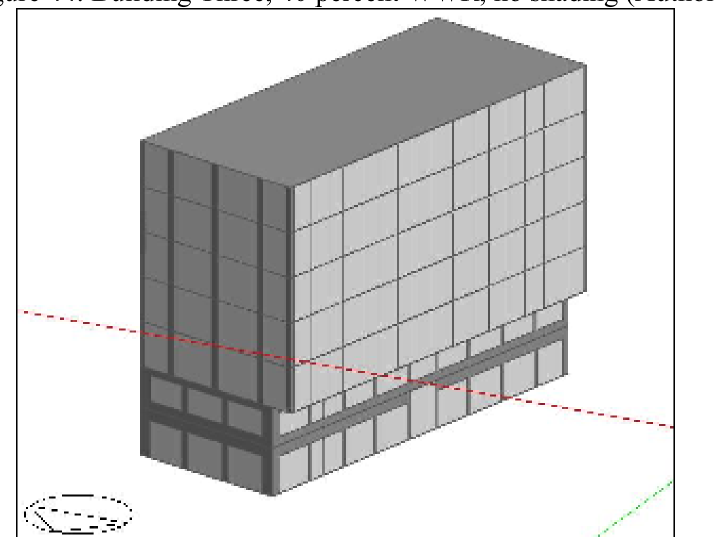
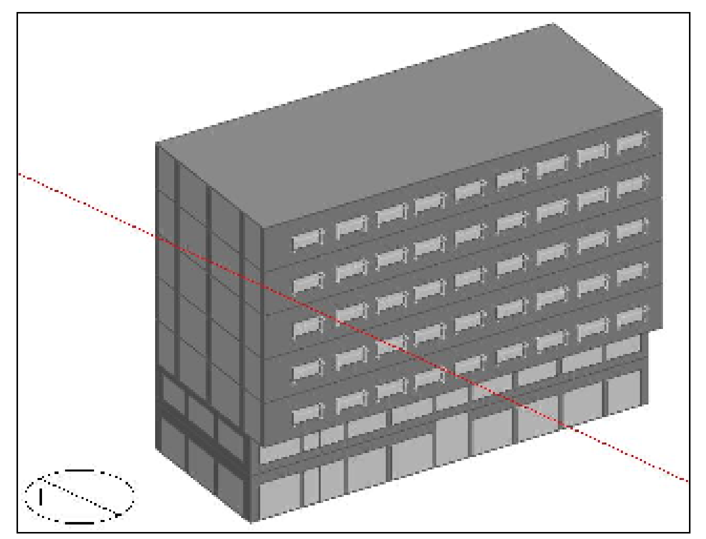
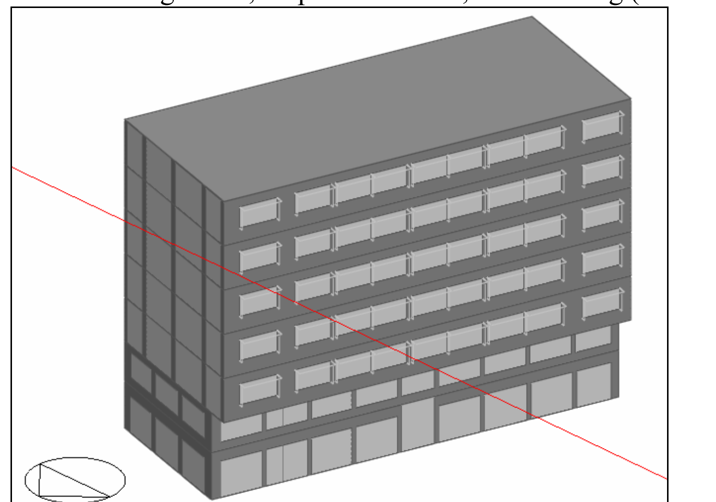


Figure 45: Building Three, 100 percent WWR, no shading (Author)


Figure 46: Building Three, 20 percent WWR, with shading (Author)


Figure 47: Building Three, 40 percent WWR, with shading (Author)

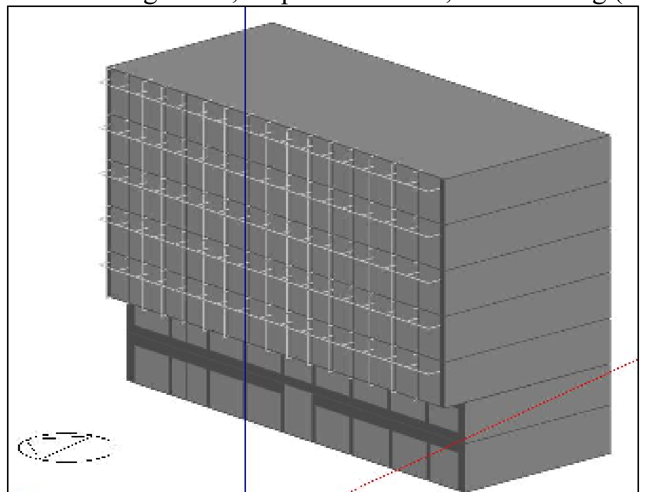

Figure 48: Building Three, 100 percent WWR, with shading (Author)

Table 50: Parametric Cases annual results for building Three NW Orientation. (Author)

Building	Three	North-West Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
20	1C1	OFF	64.79419	134.2957	199.0899	ON	65.3581	128.6733	194.0314
20	1C2	OFF	52.2399	137.7344	189.9743	ON	52.80798	131.4295	184.2375
20	1C3	OFF	49.89694	138.7206	188.6175	ON	50.46324	132.2909	182.7542
20	1E1	OFF	58.08416	139.0188	197.103	ON	58.4621	133.8965	192.3586
20	1E2	OFF	44.78918	143.618	188.4071	ON	45.18556	137.8497	183.0353
20	1E3	OFF	42.24946	144.9162	187.1657	ON	42.64715	139.0217	181.6688
20	2C1	OFF	56.45891	136.1306	192.5896	ON	56.77713	131.5505	188.3276
20	2C2	OFF	43.63851	140.0485	183.687	ON	43.95537	134.9168	178.8722
20	2C3	OFF	41.19838	141.1775	182.3759	ON	41.51292	135.9495	177.4625
20	2E1	OFF	53.39662	136.9884	190.385	ON	53.60118	132.899	186.5002
20	2E2	OFF	40.38004	141.196	181.5761	ON	40.58338	136.6144	177.1977
20	2E3	OFF	37.87873	142.4181	180.2968	ON	38.07807	137.7464	175.8245

Building	Three	North-West Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
40	1C1	OFF	66.8923	140.9889	207.8812	ON	71.11776	126.1236	197.24141
40	1C2	OFF	55.0647	144.7989	199.86361	ON	59.2311	128.4259	187.65696
40	1C3	OFF	52.9415	145.7974	198.73887	ON	57.0912	129.1391	186.23034
40	1E1	OFF	58.8611	146.5525	205.4136	ON	62.5773	132.1006	194.67787
40	1E2	OFF	46.1423	151.7591	197.90136	ON	49.84975	135.7012	185.55099
40	1E3	OFF	43.7907	153.1055	196.89613	ON	47.49949	136.7363	184.23583
40	2C1	OFF	57.2705	142.3579	199.62834	ON	60.55816	129.5493	190.10746
40	2C2	OFF	45.1141	146.6828	191.79685	ON	48.36326	132.5077	180.87101
40	2C3	OFF	42.8749	147.8291	190.70401	ON	46.11708	133.3943	179.5114
40	2E1	OFF	53.7512	142.89	196.64124	ON	56.66333	130.9837	187.64705
40	2E2	OFF	41.3614	147.5403	188.90171	ON	44.23504	134.3076	178.54264
40	2E3	OFF	39.0545	148.7837	187.83816	ON	41.91964	135.3017	177.22137

Building	Three	North-West Orientation							
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
100	1C1	OFF	67.70923	163.7938	231.503	ON	77.74747	134.5547	212.3022
100	1C2	OFF	57.88735	167.9145	225.8018	ON	67.7476	136.6895	204.4371
100	1C3	OFF	56.31022	168.7793	225.0895	ON	66.14924	137.2501	203.3994
100	1E1	OFF	55.2421	175.6399	230.882	ON	64.34295	144.5341	208.8771
100	1E2	OFF	44.51428	181.9828	226.4971	ON	53.49212	148.2417	201.7339
100	1E3	OFF	42.72969	183.2887	226.0184	ON	51.70751	149.1233	200.8308
100	2C1	OFF	54.03174	167.9669	221.9986	ON	61.882	141.4523	203.3343
100	2C2	OFF	43.96779	172.9995	216.9673	ON	51.73096	144.4062	196.1372
100	2C3	OFF	42.30973	174.0632	216.373	ON	50.06421	145.1353	195.1995
100	2E1	OFF	49.05267	169.6373	218.69	ON	56.20952	143.8742	200.0837
100	2E2	OFF	38.74747	175.2227	213.9702	ON	45.8215	147.2984	193.1199
100	2E3	OFF	37.02621	176.4024	213.4286	ON	44.09043	148.133	192.2234

3-7 Building Four (North-East Orientation)

3-7-1 Location:

Building Four is located on Wasfi Attal Street, city of Amman, where the main façade is oriented to the North- East. See figure (49).

3-7-2 Design:

The building consists of a retail-shop functioned ground floor, an outdoor arcade, a mezzanine floor, and five typical- plan stories holding offices. See photo (4) for an actual image of the building, and figure (50) for a modeled image of the building.

Based on the original plans and elevations, obtained from management crew of the building, the building's typical floor layout was modeled as shown in figure (51), with an approximate area of **(600) m^2/floor**, 4200 m^2 in total

The main façade, which is oriented to the North-East Orientation, consist of light brown colored glazing and stone cladding on external walls. The rest of the building has rough plastering material, with light color and a limited number of openings.

3-7-3 Base Case Simulation:

Base case Results for annual heating and cooling requirements are shown in table (51). The results are normalized per meter square of area.

Table 51: Base case results, Building Four. (Author)

Name	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2
Base Case Building Four NE	48.2296	110.046	158.2758



Figure 49: Building Four, North-East Orientation, Madina St. (GoogleEarth®, 2011)



Photo 4: Actual image of Building Four, taken in Feb 2011

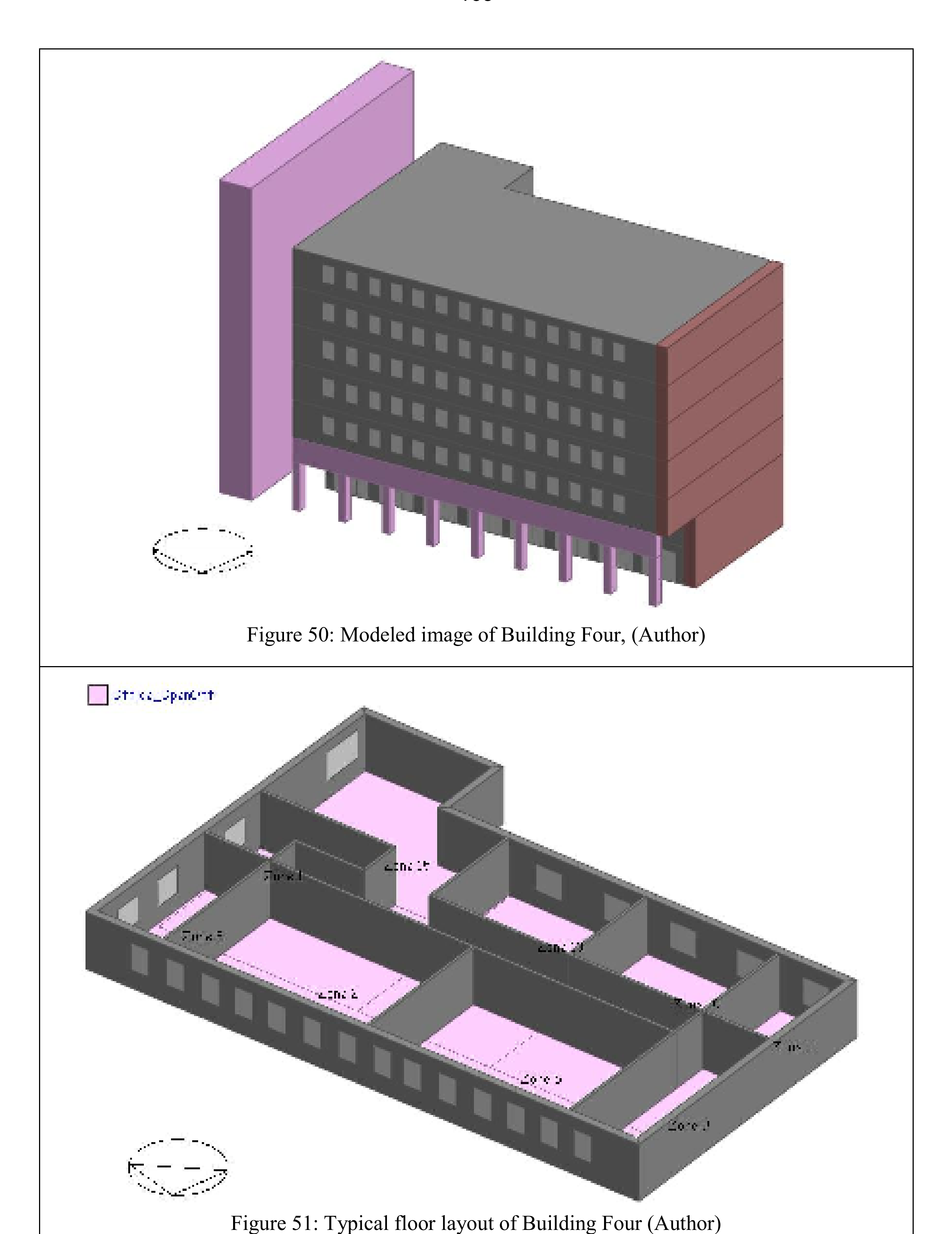


Figure 50: Modeled image of Building Four, (Author)

Figure 51: Typical floor layout of Building Four (Author)

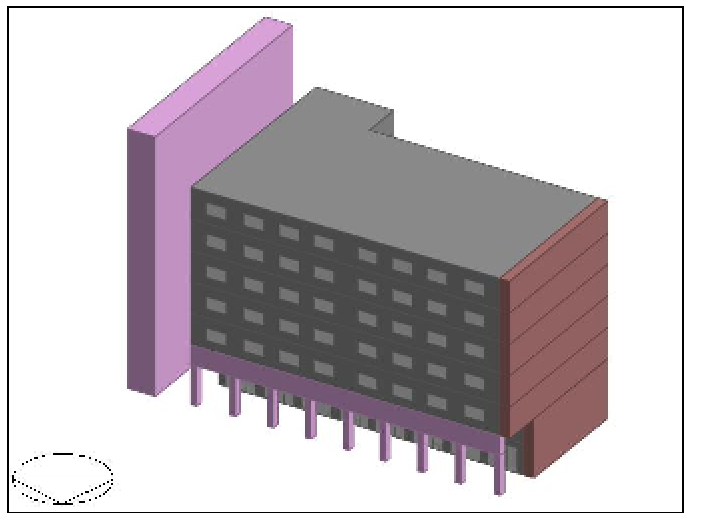
3-7-4 Parametric Cases Simulation:

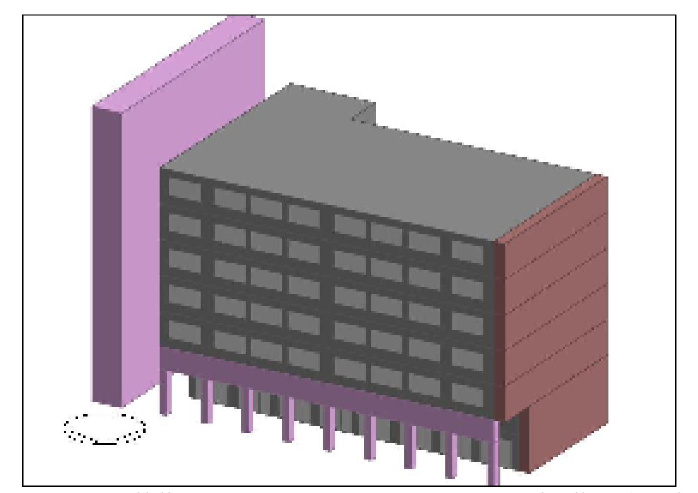
Figures (52), (53) and (54) show the parametric cases of 20 percent WWR, 40 percent WWR and 100 percent WWR, respectively, without any shading. On the other hand, figures (55), (56) and (57) show the parametric cases of 20 percent WWR, 40 percent WWR and 100 percent WWR, respectively, with shading.

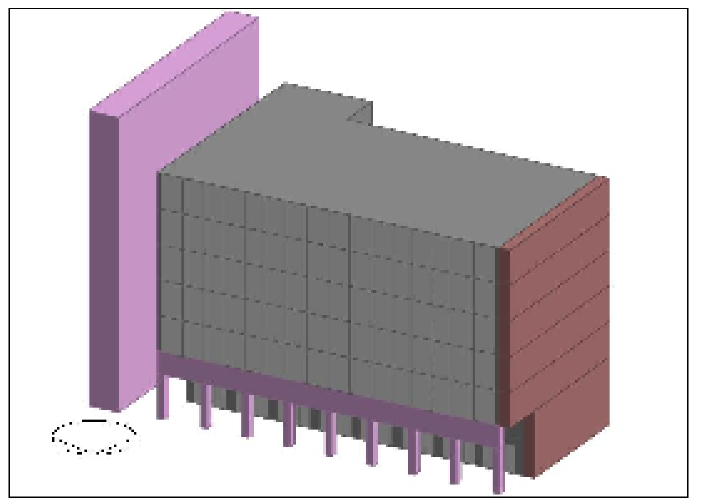
Table (52) shows the annual heating and cooling demand. The results were normalized per meter square of area, in order to compare the result with the base case results.

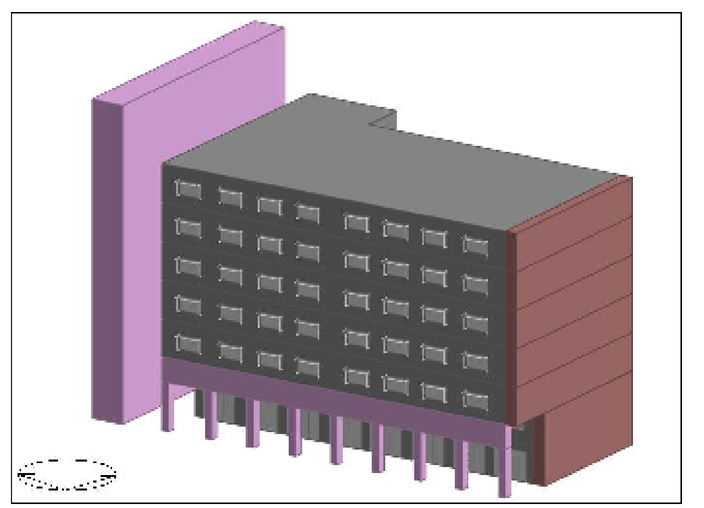
Cases are color coded in table (52) to represent the following:

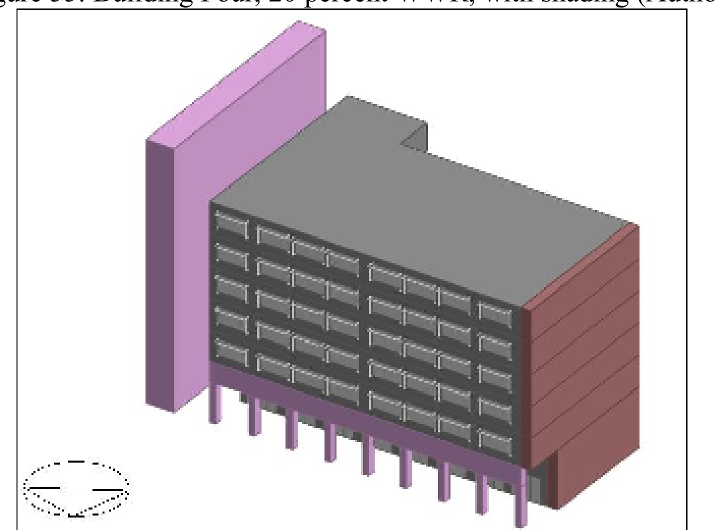
7) Cases in Red represent cases with the lowest energy demand needed for heating.
8) Cases in Orange represent cases with the highest energy demand needed for heating.
9) Cases in Dark blue represent cases with the lowest energy demand needed for cooling.
10) Cases in Light blue represent cases with the highest energy demand needed for cooling.
11) Cases in Green represent cases with the lowest total heating and cooling energy demand.
12) Cases in yellow represent cases with the highest total heating and cooling energy demand.


Figure 52: Building Four, 20 percent WWR, no shading (Author)


Figure 53: Building Four, 40 percent WWR, no shading (Author)


Figure 54: Building Four, 100 percent WWR, no shading (Author)


Figure 55: Building Four, 20 percent WWR, with shading (Author)


Figure 56: Building Four, 40 percent WWR, with shading (Author)

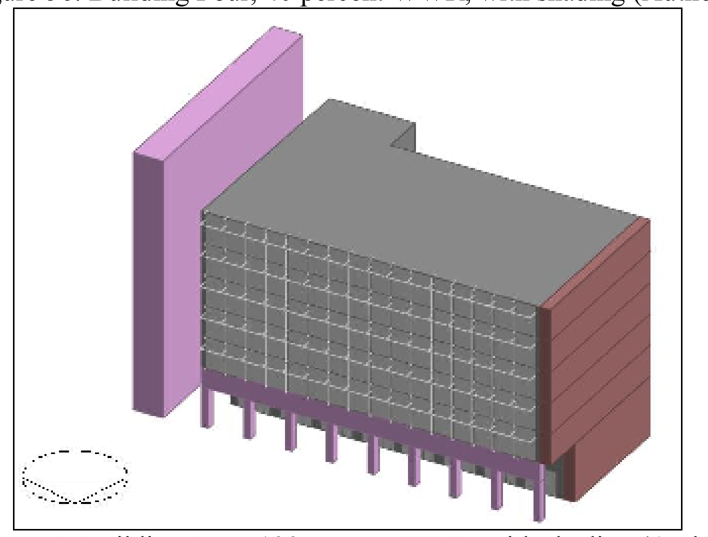

Figure 57: Building Four, 100 percent WWR, with shading (Author)

Table 52: Parametric Cases annual results, Building Four NE Orientation (Author)

Building	Four								
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
20	1C1	OFF	47.52726	110.6432	158.1705	ON	46.36152	112.7181	159.0796
20	1C2	OFF	36.97828	113.5209	150.4992	ON	35.87348	115.6889	151.5624
20	1C3	OFF	35.11928	114.418	149.5373	ON	34.02471	116.6181	150.6428
20	1E1	OFF	44.22592	113.2996	157.5256	ON	43.30742	115.0235	158.3309
20	1E2	OFF	33.26985	116.743	150.0128	ON	32.42373	118.5313	150.9551
20	1E3	OFF	31.30277	117.7909	149.0937	ON	30.47236	119.6068	150.0791
20	2C1	OFF	43.20007	112.5933	155.7933	ON	42.42283	114.1895	156.6123
20	2C2	OFF	32.41711	115.8013	148.2184	ON	31.6992	117.4833	149.1825
20	2C3	OFF	30.4918	116.7956	147.2874	ON	29.78815	118.5086	148.2968
20	2E1	OFF	41.49704	113.8298	155.3269	ON	40.89634	115.1296	156.0259
20	2E2	OFF	30.62588	117.2272	147.853	ON	30.08107	118.5975	148.6785
20	2E3	OFF	28.6732	118.275	146.9482	ON	28.14122	119.6683	147.8095

Building	Four								
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
40	1C1	OFF	51.8229	109.4256	161.24856	ON	50.98462	107.9715	158.95612
40	1C2	OFF	41.8455	111.8575	153.70297	ON	41.01852	110.1565	151.17507
40	1C3	OFF	40.1678	112.5929	152.76067	ON	39.34233	110.8619	150.20426
40	1E1	OFF	47.3297	112.5701	159.89984	ON	46.5169	111.3928	157.90967
40	1E2	OFF	36.8542	115.6845	152.53875	ON	36.10792	114.252	150.35991
40	1E3	OFF	35.0398	116.5942	151.63402	ON	34.309	115.1321	149.44111
40	2C1	OFF	46.261	110.8925	157.15348	ON	45.27244	110.3109	155.58331
40	2C2	OFF	35.9886	113.6325	149.62108	ON	35.05233	112.8881	147.94041
40	2C3	OFF	34.2265	114.4632	148.68967	ON	33.30023	113.7007	147.00094
40	2E1	OFF	44.046	111.9878	156.03375	ON	43.10106	111.639	154.74009
40	2E2	OFF	33.6474	114.9324	148.57981	ON	32.76499	114.4415	147.2065
40	2E3	OFF	31.8489	115.8186	147.66751	ON	30.97821	115.3157	146.29392

Building	Four								
Size	Name	Shading	Heating	Cooling	Total	Shading	Heating	Cooling	Total
100	1C1	OFF	55.71762	116.1274	171.845	ON	58.82351	107.1571	165.9806
100	1C2	OFF	47.40819	118.0043	165.4125	ON	50.37783	108.353	158.7308
100	1C3	OFF	46.18778	118.4851	164.6729	ON	49.13914	108.7419	157.881
100	1E1	OFF	47.54036	122.9552	170.4956	ON	50.68204	113.1045	163.7865
100	1E2	OFF	38.66997	125.8402	164.5102	ON	41.74271	115.0816	156.8243
100	1E3	OFF	37.32227	126.5094	163.8317	ON	40.40213	115.6235	156.0256
100	2C1	OFF	46.69697	118.9193	165.6162	ON	48.58613	110.8322	159.4183
100	2C2	OFF	38.194	121.1761	159.3701	ON	39.98989	112.3806	152.3705
100	2C3	OFF	36.91967	121.7363	158.656	ON	38.70312	112.8489	151.5521
100	2E1	OFF	43.28376	120.7175	164.0012	ON	44.8192	112.9489	157.7681
100	2E2	OFF	34.59847	123.2479	157.8464	ON	36.08081	114.7425	150.8233
100	2E3	OFF	33.26624	123.8699	157.1362	ON	34.76197	115.2585	150.0205

3-8 Optimum Cases:

After examining between results for heating and cooling demands of different cases for the four case study buildings, it was found that cases that require lower heating demand usually require relatively high cooling demands. This is due to entrapment of heat inside the buildings generated with from low u-values and highly efficient glazing, therefore, cooling loads would be affected and consequently be higher than other cases with high u-values and clear single glazing.

However, cooling loads can be offset and lowered for the previously mentioned cases if proper natural ventilation mode is adopted in order to get rid of excess heat in some months of the year. Also, using adjustable shading, either manually or automatically, will benefit from the advantages of shading devices in the summer season, and automatically adjust the shading devices to whenever shading is not needed, in other words, the winter season, when heating is desired.

This kind of optimization is evaluated through the simulation of the case which has the lowest heating demand requirement in the winter, and providing adjustable shading devices by simulating only the summer season for the case with shading devices. The results of the two seasons would be added together to create the optimum case.

3-8-1 Building One, South West Orientation

From table (46), the case which has the lowest heating demand requirements are the cases with double Low-E glazing and maximum green building insulation requirement, (see paragraph 3-3-10) with no shading, regardless of the size of opening, 20, 40 or 100 percent of Window to Wall area ratio. When adding shading only in the summer season, the case of 40 percent WWR becomes the optimum case. Table (53) shows the results of the optimum case for Building One, South West Orientation, and savings compared with the base case.

Table 53: Optimum case, Building One, SW Orientation (Author)

Case name	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2	Saving in Heating %	Saving in Cooling %	Saving in Total %
40 2E3 Adjust	37.5428	152.976	190.518	39	6	15

3-8-2 Building Two, South East Orientation:

From table (48), the case which has the lowest heating demand requirements are the cases with double Low-E glazing and maximum green building insulation requirement, (see paragraph 3-3-10) with no shading, regardless of the size of opening, 20, 40 or 100 percent of Window to Wall area ratio. When adding shading only in the summer season, the case of 20 percent WWR becomes the optimum case.

Table (54) shows the results of the optimum case for Building Two, South East Orientation, and savings compared with the base case.

Table 54: Optimum case, Building Two, SE Orientation (Author)

Case Name	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2	Saving in Heating %	Saving in Cooling %	Saving in Total %
20 2E3 Adjust	26.7607	123.679	150.4399	54	28	34

3-8-3 Building Three, North West Orientation:

From table (50), the case which has the lowest heating demand requirements are the cases with double Low-E glazing and maximum green building insulation requirement (see paragraph 3-3-10) with no shading, regardless of the size of opening, 20, 40 or 100 percent of Window to Wall area ratio. When adding shading only in the summer season, the case of 40 percent WWR becomes the optimum case.

Table (55) shows the results of the optimum case for Building Three, North-West Orientation, and savings compared with the base case

Table 55: Optimum case, Building Three, NW Orientation (Author)

	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2	Saving in Heating %	Saving in Cooling %	Saving in Total %
40 2E3 Adjust	39.0545	135.302	174.3562	34.5	8.	15.5

3-8-4 Building Four, North East Orientation:

From table (52) the case which has the lowest heating demand are the cases with double Low-E glazing and maximum green building insulation requirement (see paragraph 3-3-10). In this case, there was no significant difference between cases with shading and without. This is due to the location and orientation of main façade of building four, the North- East orientation.

Thereafter, it is more feasible to not include shading at all on this façade, hence the optimum case would become the 40 percent WWR case with double Low-E glazing and no shading.

Table (56) shows the results of the optimum case for Building Four, North East orientation, and savings compared with the base case.

Table 56: Optimum case, Building Four, NE Orientation. (Author)

	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2	Saving in Heating %	Saving in Cooling %	Saving in Total %
40 2E3 none	31.8489	115.819	147.6675	34	-5	7

CHAPTER FOUR (IV)

RESULTS AND DISCUSSIONS

CHAPTER 4

RESULTS AND DISCUSSIONS

4-1 General:

Results for All four buildings (Case Study) with four different skewed-cardinal orientations for main (long) facades, were obtained from the thermal simulation outputs generated by the DesignBuilder® software for 288 cases, 72 for each building.

Tables (46), (48), (50) and (52) show all of the annual heating, cooling and total energy consumption for all of the cases, in addition to Appendix D which shows monthly energy consumption for all of the cases.

This chapter addresses results in order to analyze them and generate discussions in comparison with other case studies.

4-2 Building One, South-West Orientation:

Graph 1 shows the classification of energy consumption in building One, South-West facing.

It was found that the higher the WWR, the higher the energy demand, regardless of type of glazing or insulation.

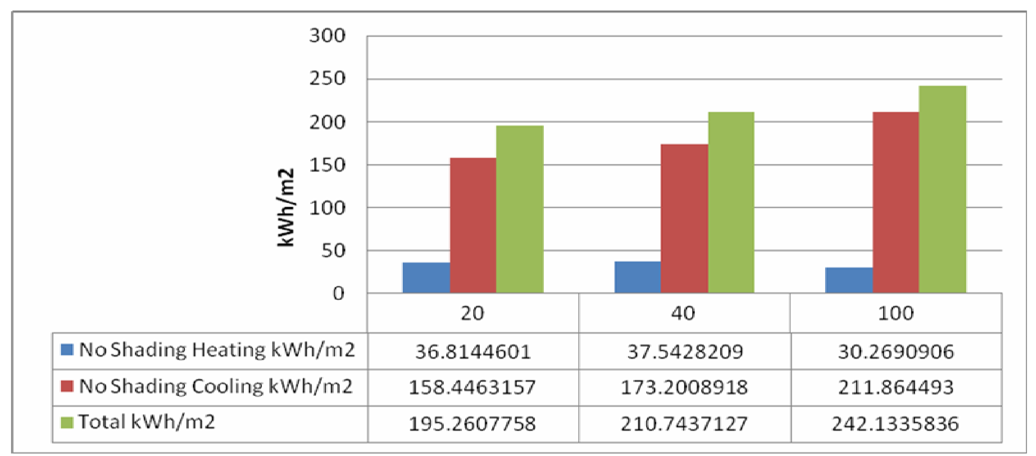
In addition, it was found that more than **80 percent** of the energy consumption is dedicated to space cooling and **20 percent** goes to space heating. This shows that cooling demand is more important to rationalize than heating demand, although it is also important to look at for lowering heating loads.

When comparing these results with residential buildings, we find that commercial buildings consume more energy for cooling, while residential buildings have higher heating demand.

Graph 2 shows heating, cooling and total energy consumption for Building One, the South- West facing building, for shaded and un-shaded cases, when using double low-e glazing.

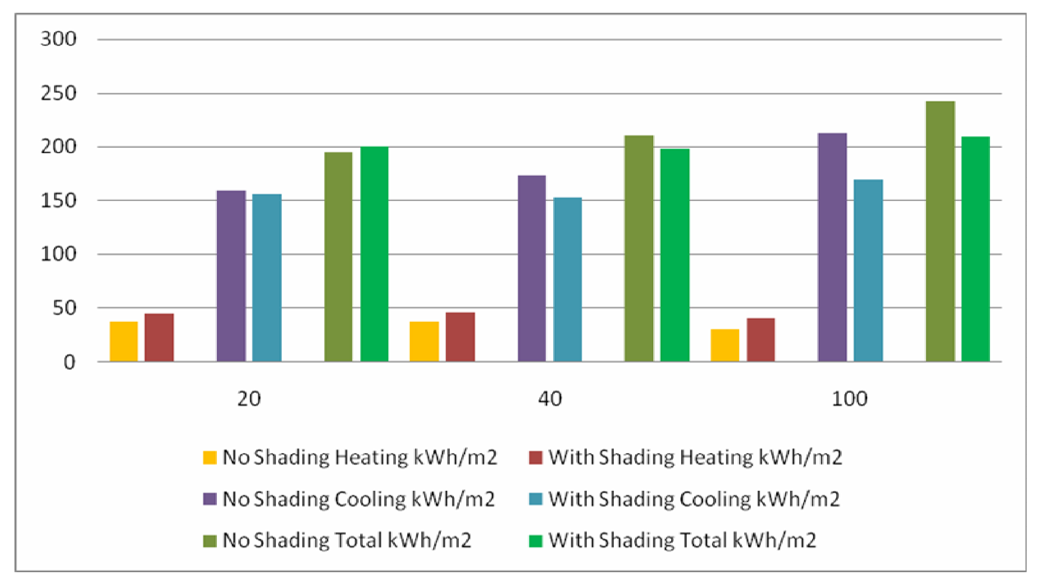
It is concluded that shading can affect heating demand **negatively** by increasing the heating demand between **10 and 20 percent**. On the other hand, **energy saving** for cooling **increases** reaching more than **30 percent** for shaded cases compared with un-shaded areas.

Graph 2 also indicates that the higher the WWR, the more positive affect shading devices offer. This means that it is important to invest in shading devices for buildings which are South-West oriented and with high WWR.



	20	40	100
No Shading Heating kWh/m2	36.8144601	37.5428209	30.2690906
No Shading Cooling kWh/m2	158.4463157	173.2008918	211.864493
Total kWh/m2	195.2607758	210.7437127	242.1335836

Graph 1: Heating, cooling and total energy consumption for building One, Double Low-e glazing, with no shading. (Author)



Graph 2: Heating, cooling and total energy consumption for building One, Double Low-e glazing, for shaded and un-shaded cases. (Author)

Graph 3 shows heating consumption for Building One, for cases with different WWRs and different U-values. It also illustrates the difference between heating demand for both shaded and un-shaded cases.

It was found that heating demand can be lowered by more than **40 percent** for low WWR, and more than **25 percent** for high WWR, when comparing between un-insulated cases and cases achieving the Energy Efficient Building Code minimum requirement of U-value 0.57 kW/m^2.k.

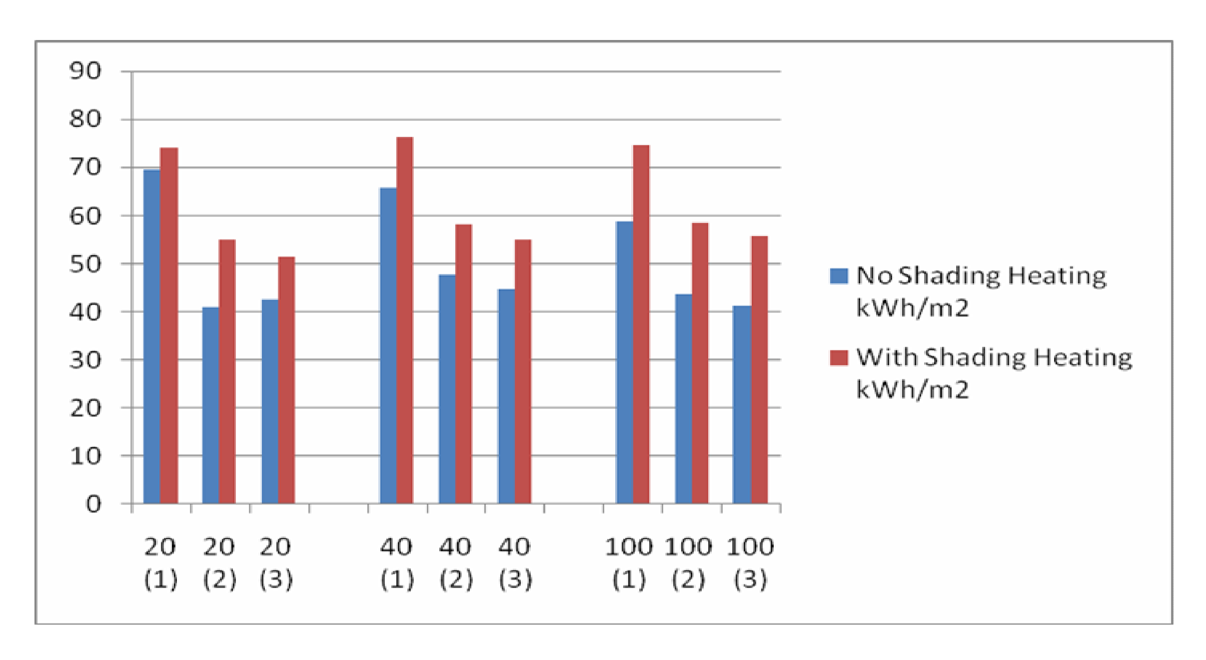
On the other hand, difference in heating consumption between cases achieving the Energy Efficient Building Code minimum requirement of U-value 0.57 kW/m^2.k, and the Green building guideline U-value requirement of 0.45 kW/m^2.k are very low. Savings can be less than **6 percent** between the previously mentioned cases.

This concludes that it is more feasible to comply with the minimum U-value requirements of the Energy Efficient Building Code of Jordan only, without investing in more than that, in South-West facing Buildings.

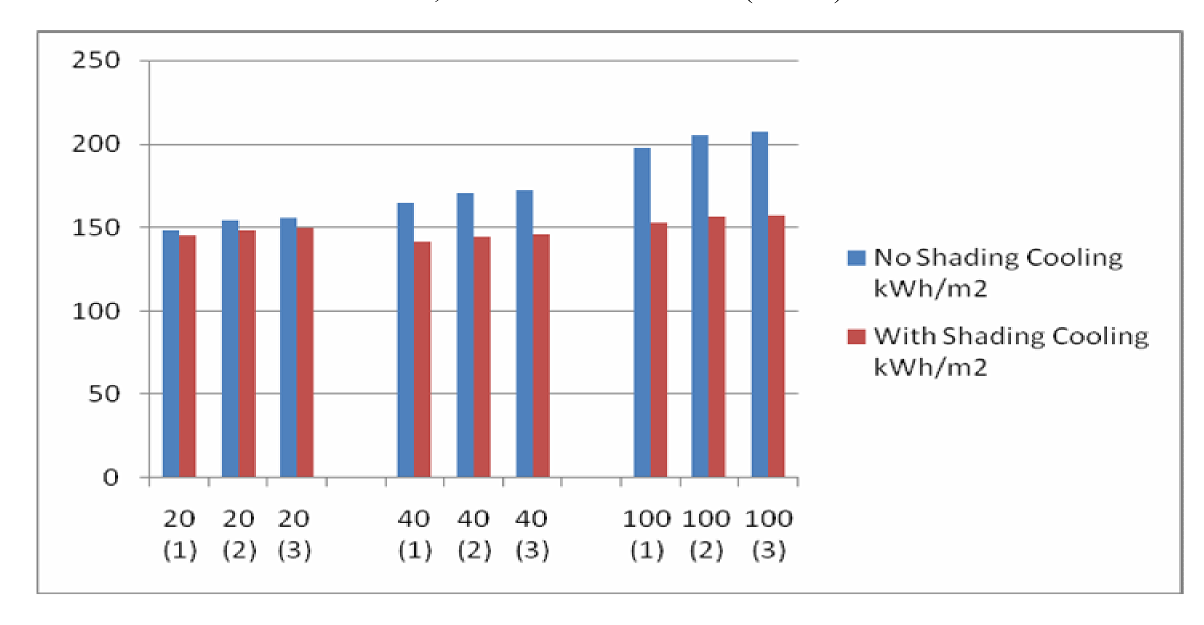
Moreover, Graph 3 shows that shading could increase the heating demand by **27 percent** for high WWR, and by **19 percent** for low WWR. This concludes the illegible use of adjustable shading devices whenever possible. And if not, shading devices should be added to facades with high WWR, in order to lower the high energy demands required for space cooling, despite the fact they negatively affect the heating demand. See Graph 4.

Graph 4 shows cooling consumption for Building One, for cases with different WWRs and different U-values. It also illustrates the difference between cooling demand for both shaded and un-shaded cases.

It was found that cooling demand decreases significantly by **24 percent** in energy savings for high WWR. On the other hand, cases with low WWR shading have almost **NO** effect on cooling savings.



Graph 3: Heating consumption for building One, Single Clear Glazing, for shaded and un-shaded cases, with different U-values*. (Author)



Graph 4: Cooling consumption for building One, Single Clear Glazing, for shaded and un-shaded cases, with different U-values*. (Author)

* (1) indicates no insulation with 1.8 $kW/m^2.k$ U-values.
(2) indicates Energy Efficient Building Code insulation requirement with 0.57 $kW/m^2.k$ U-values.
(3) indicates Green building guideline of Jordan insulation requirement with 0.45 $kW/m^2.k$ U-values

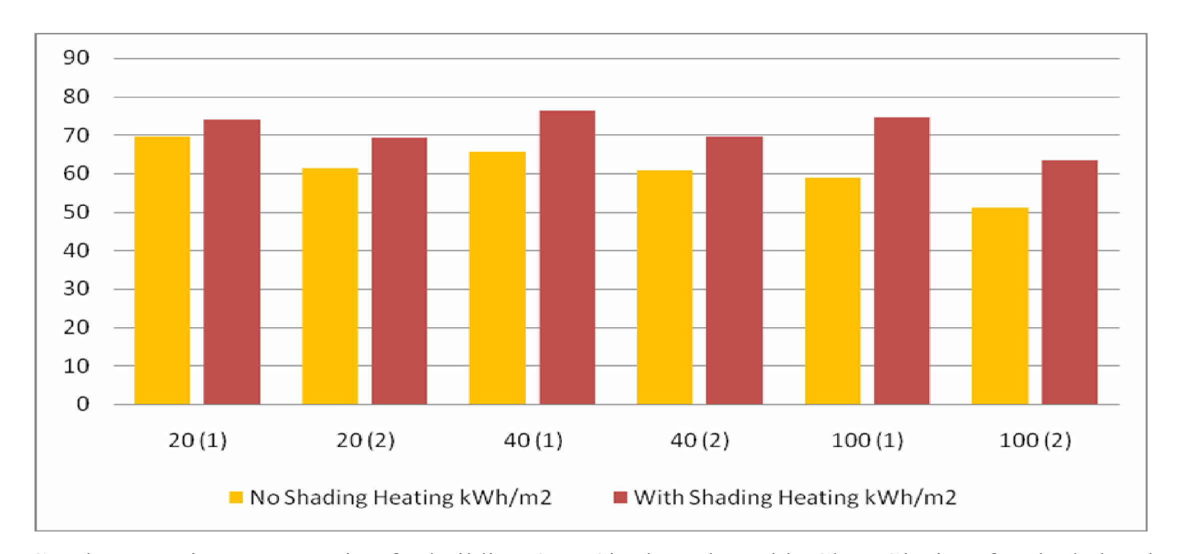
Moreover, cooling demand increases slightly, by less than **7 percent**, when comparing un-insulated cases with cases complying with the minimum U-value requirement. This indication does **NOT** illuminate the importance of complying with minimum U-value required by the Energy Efficient Building Code

Furthermore, it is concluded that South-West facing buildings shading can positively affect the total energy consumption for high WWR facades. Conversely, external fixed shading devices is NOT that important for facades with low WWR, were the depth of the window inside the wall is enough to provide the required shading, especially in Summer.

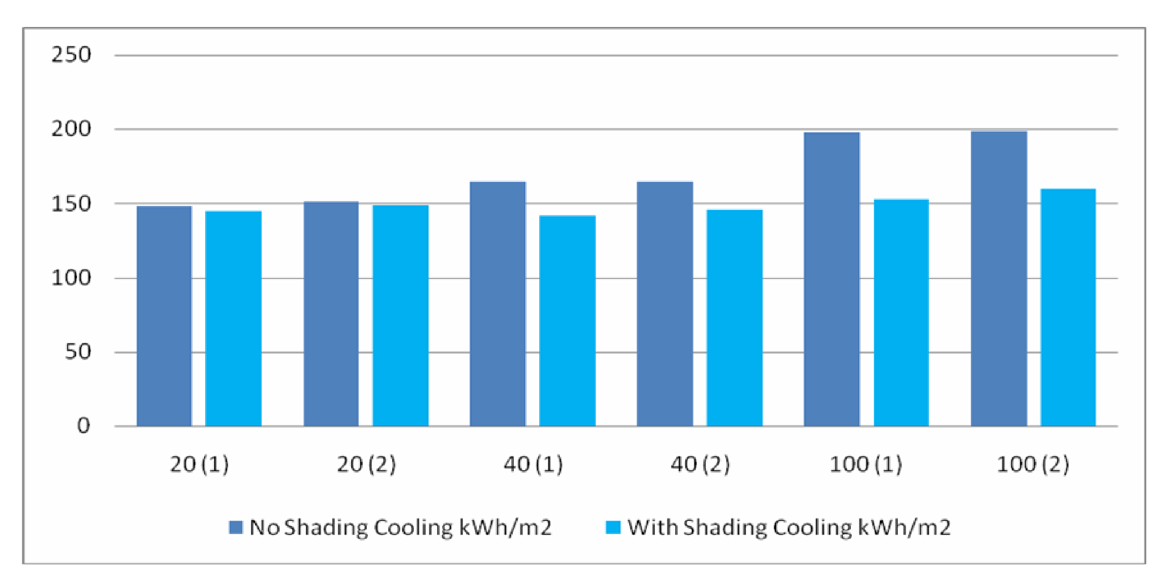
Graph 5 indicates heating demand for cases with clear single and double glazing, compared between different WWRs and shaded and un-shaded cases.

Results show that more than **15 percent** of the heating demand can be saved when using double glazing when compared with single glazing.

However, in Graph 6, which indicates cooling demand for cases with clear single and double glazing compared between different WWRs and shaded and un-shaded cases, it can be concluded that whichever type of glazing is used, it has almost **NO** effect on energy consumption needed for space cooling for buildings with South-West orientation.



Graph 5: Heating consumption for building One, Single and Double Clear Glazing, for shaded and un-shaded cases, with no insulation*. (Author)



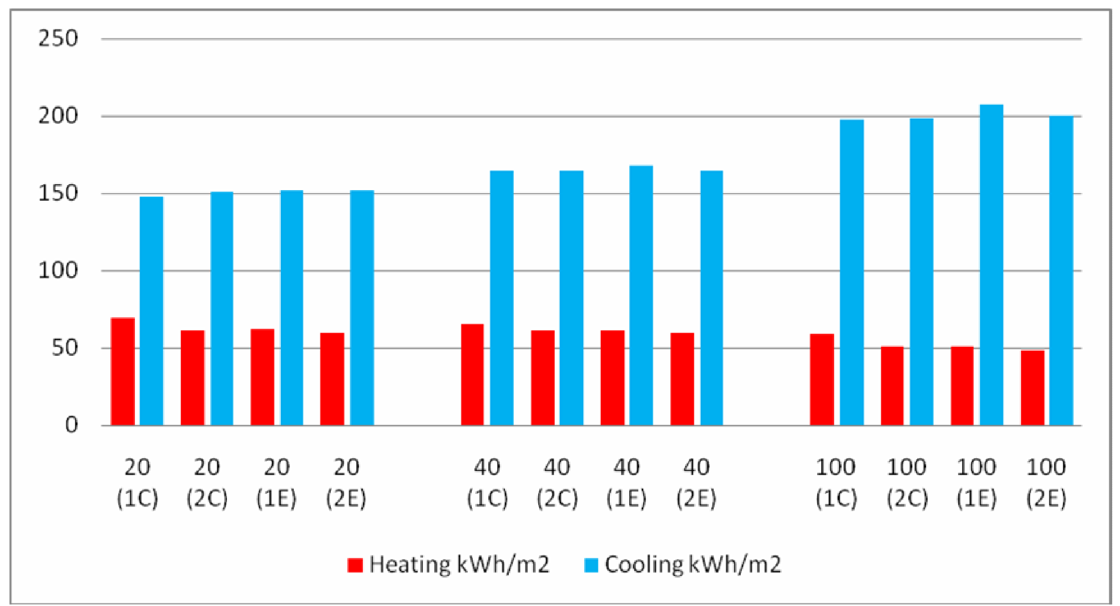
Graph 6: Cooling consumption for building One, Single and Double Clear Glazing, for shaded and un-shaded cases, with no insulation*. (Author)

* (1) indicates Clear Single glazing.
(2) indicates Clear Double glazing.

Graph 7 indicates the effect of using Low-e glazing compared with clear glazing, for both single and double glazing, on heating and cooling demands for building One, South-West Orientation, with no insulation and no shading.

It was found that using double clear glazing gives almost the same effect of Single low-e glazing in energy consumption used for space heating.

However, in energy consumption used for space cooling, the type of glazing almost have no effect of savings for low WWR facades. On the other hand, for facades with high WWR, it is recommended **NOT** to use single low-e glazing, and recommended to use double clear or Low-e glazing instead.

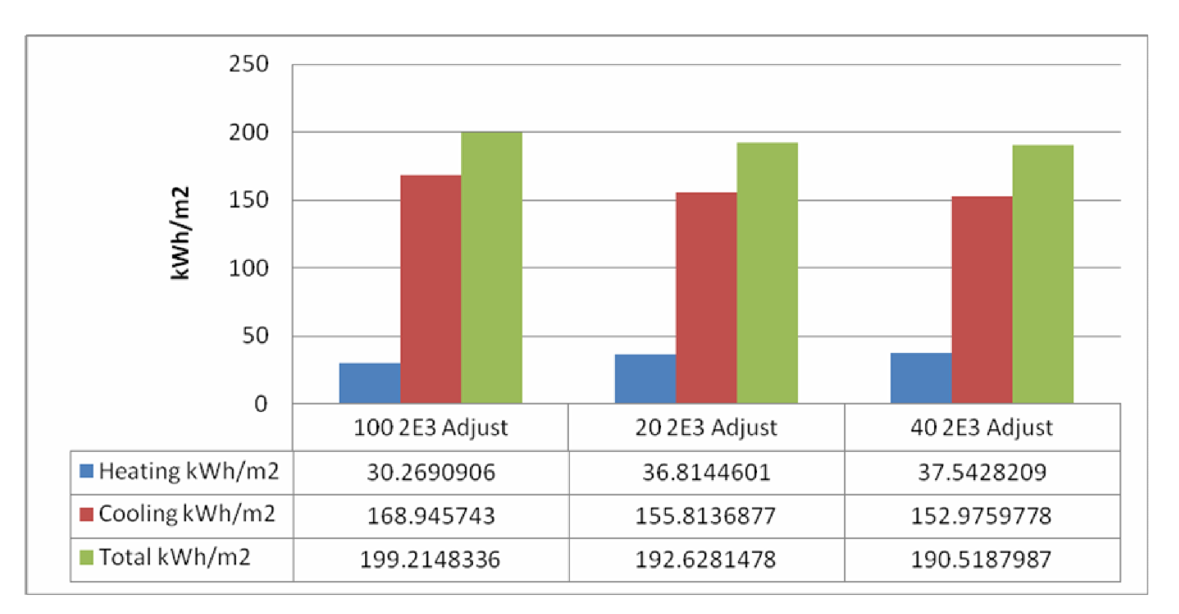


Graph 7: Heating and cooling demand for Building One, using different types of glazing.* (Author)

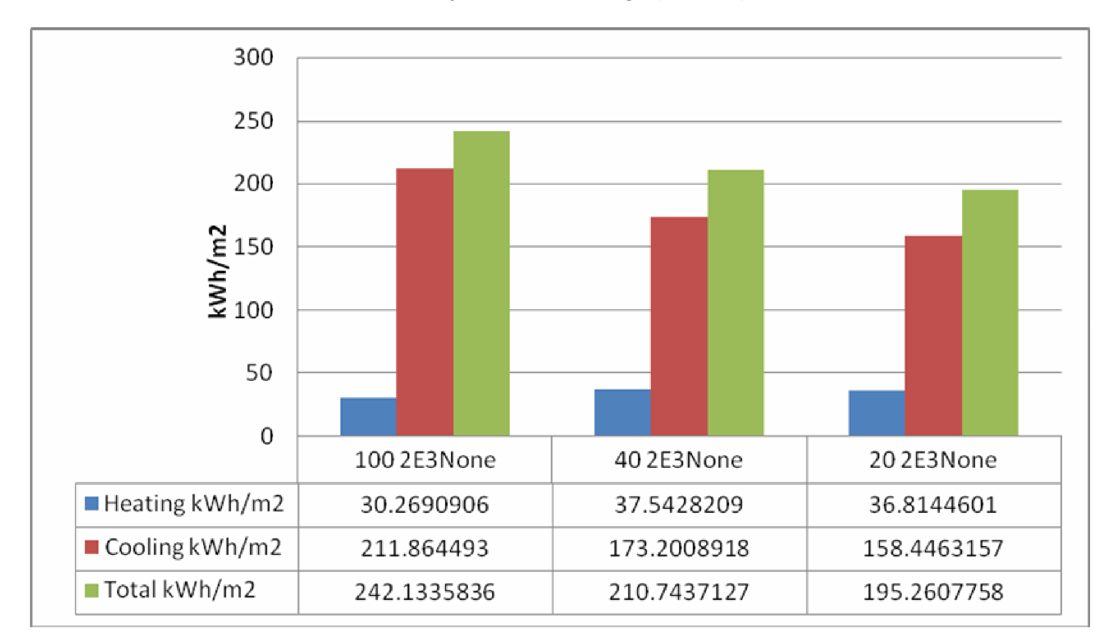
* (1C) indicates Single Clear Glazing
(2C) indicates Double Clear Glazing
(1E) indicates Single Low-e Glazing
(2E) indicates Double Low-e Glazing

Graph 8 shows heating, cooling and total energy consumption when using adjustable shading devices in facades with double low-e glazing, where shading devices are only ON when they are needed, i.e. in the summer season. Graph 9 shows the same parameters but with no shading.

When comparing graph 8 with graph 9 for building One, the South-West facing building, it was found that energy needed for space heating is still the same for both cases, indicating the use of un-shaded façade in winter. Moreover, when using adjustable shading in the summer. Graph 8 shows that cooling demand has been lowered by **20 percent** for high WWR in comparison with the un-shaded case, and leading to a lower value of total energy consumption reaching saving of **17 percent** for high WWR.



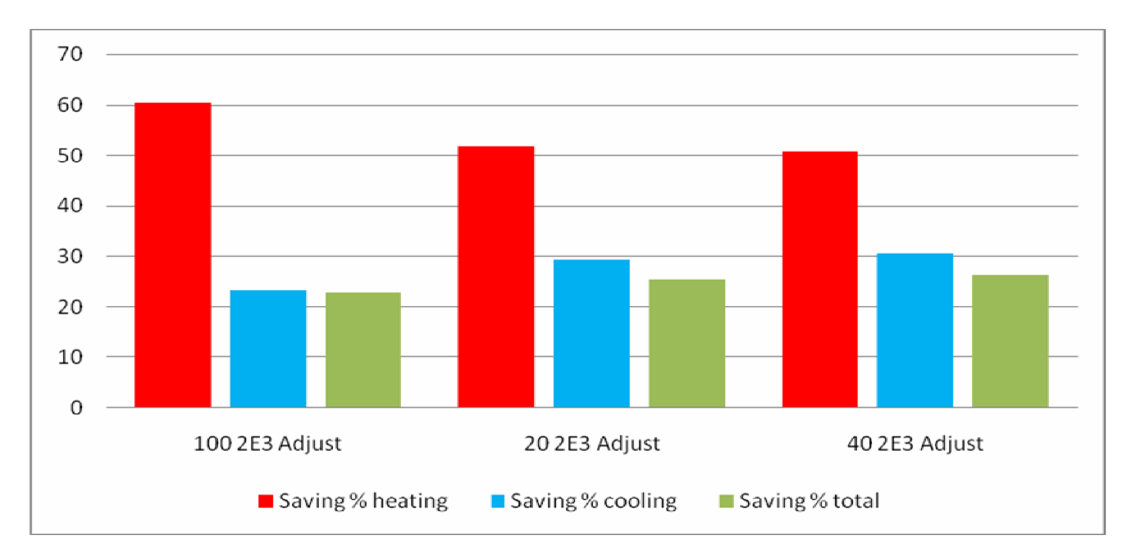
Graph 8: Heating, cooling and total energy consumption for building One, Double Low-e glazing, with adjustable shading. (Author)



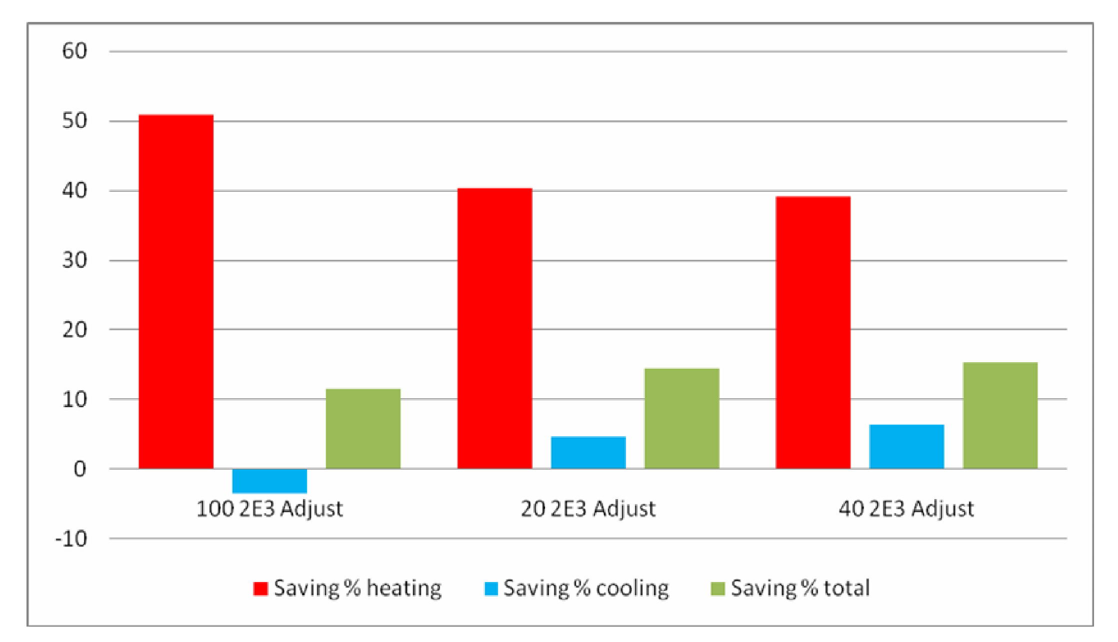
Graph 9: Heating, cooling and total energy consumption for building One, Double Low-e glazing, with no shading. (Author)

However, the use of adjustable shading device is more expensive than using fixed external one. This concludes, that unless nessecary, adjustable shading is most recommended to be used for buildings with high WWR facades, and not to be used for facades with low WWR.

Graph 10 illustrates savings (in percentage) in heating, cooling and total energy consumption for Building One when using adjustable shading devices and double Low-e glazing for un-insulated building envelope, compared with worst cases results. See table (1) However, graph 11 shows savings for the same parameters but in comparison with the results of the Base case.



Graph 10: Savings (in percentage) in heating, cooling and total energy consumption when using djustable shading devices in comparison with worst case senario, Building One, SW. (Author)



Graph 11: Savings (in percentage) in heating, cooling and total energy consumption when using djustable shading devices in comparison with worst case senario, Building One, SW. (Author)

Table (57) summeries the energy consumption results of the simulation of Building One, the South-West Orientation, and savings compared with worst case senarios and savings compared with base case design senario for the following:

1) **Base case**
2) **Optimum cases (with adjustable shading devices)**
3) **Best cases**
4) **Worst cases**

Table (58) signifies the descending order of design senarios for Building One, the South-West Orientation, from the best case recommended for South-West Facing buildings, to the worst case design senario, which should be forbiddened in South-West facing Buildings.

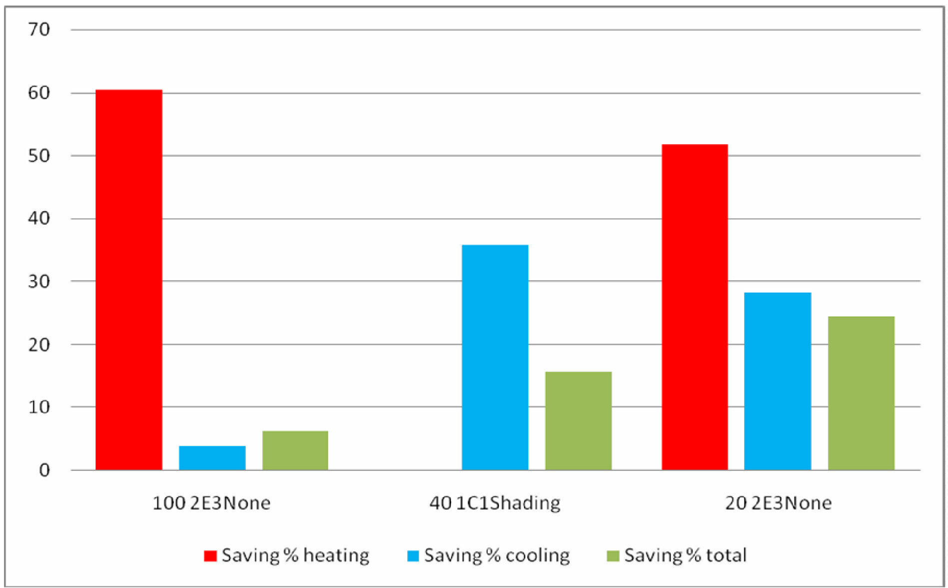
Graph 12 illustrates savings (in percentage) in heating, cooling and total energy consumption for Building One when using best case senarios, compared with results of worst cases of the research. See table (57). However, graph 13 shows savings for the same parameters but in comparison with the results of the Base case design senario.

Table 57: Summary of results for Building One, South-West Orientation (Author)

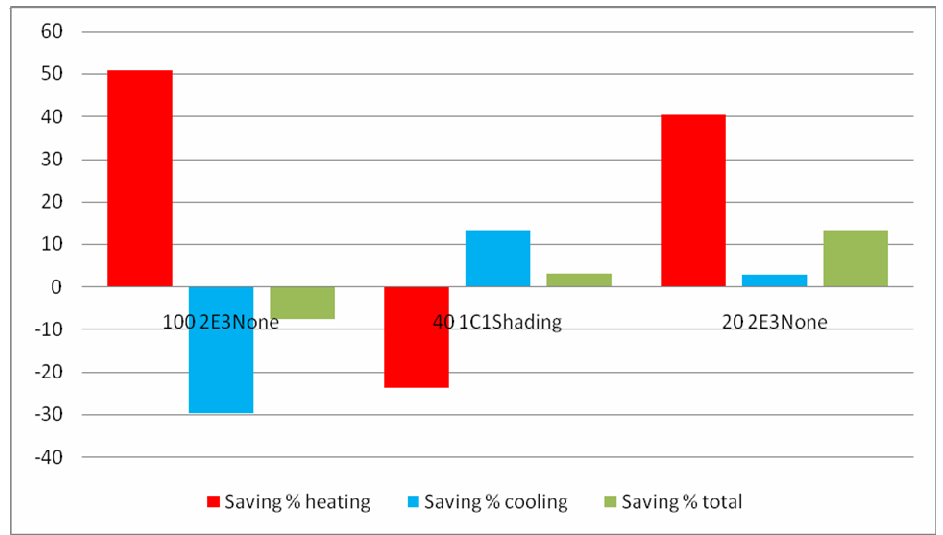
	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2	Compared with worst			Compared with Base		
				Saving% heating	Saving% cooling	Saving % total	Saving% heating	Saving% cooling	Saving % total
Base	61.61	163.12	224.74	19.3	26.1	13.1	0	0	0
Optimum									
100 2E3 Adjust	30.26	168.94	199.21	60.4	23.4	22.9	50.9	-3.6	11.4
20 2E3 Adjust	36.81	155.81	192.62	51.7837	29.4	25.5	40.3	4.5	14.3
40 2E3 Adjust	37.54	152.97	190.51	50.8297	30.7	26.3	39.1	6.2	15.2
Best									
100 2E3 None	30.26	211.86	242.13	60.3	4.0	6.3	50.9	-29.9	-7.7
40 1C1Shading	76.35	141.71	218.06	0	35.8	15.6	-23.9	13.1	3.0
20 2E3 None	36.81	158.44	195.26	51.8	28.2	24.5	40.3	2.9	13.1
Worst									
40 1C1Shading	76.35	141.71	218.06	0	35.8	15.6	-23.9	26.1	3.0
100 1E3 None	32.58	220.62	253.20	57.3	0	2.1	47.1	-35.2	-12.7
100 1E1 None	50.97	207.53	258.51	33.2	5.9	0	17.3	-27.2	-15.0

Table 58: Descending Order of Design case scenarios for Building One, South-West Orientation, from Best to worst. (Author)

	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2
40 2E3 Adjust	37.54	152.97	190.51
20 2E3 Adjust	36.81	155.81	192.62
20 2E3 None	36.81	158.44	195.26
100 2E3 Adjust	30.26	168.94	199.21
40 1C1 Shading	76.35	141.71	218.06
100 2E3 None	30.26	211.86	242.13
100 1E3 None	32.58	220.62	253.20
100 1E1 None	50.97	207.53	258.51



Graph 12: Savings (in percentage) in heating, cooling and total energy consumption when using best case design senario in comparison with worst case senario, Building One, SW. (Author)



Graph 13: Savings (in percentage) in heating, cooling and total energy consumption when using best case design senario in comparison with base case senario, Building One, SW. (Author)

4-3 Building Two, South-East Orientation:

Graph 14 shows the classification of energy consumption in building Two, the South-East facing building.

It was found that the higher the WWR, the higher the energy demand, regardless of type of glazing or insulation.

In addition, it was found that more than **88 percent** of the energy consumption is dedicated for space cooling and **12 percent** goes to space heating. This shows that cooling demand is more important to rationalize than heating demand, although it is also important to look at for lowering heating loads.

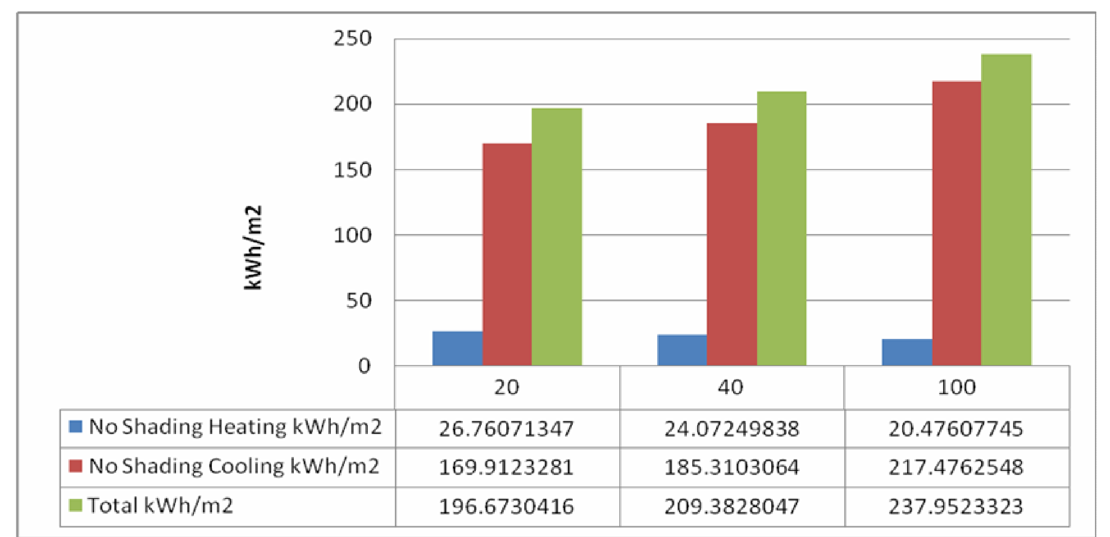
Graph 15 shows heating, cooling and total energy consumption for Building Two, the South- East facing building, for shaded and un-shaded cases, when using double low-e glazing.

It is concluded that shading can affect heating demand **negatively** by increasing the heating demand between **35 and 45 percent**. On the other hand, **energy saving** for cooling **increases** reaching more than **35 percent** for shaded cases compared with un-shaded cases.

Graph 15 also indicates that the higher the WWR, the more positive efficiency shading devices offer. This means that it is important to invest in shading devices for buildings which are South-East oriented and with high WWR.

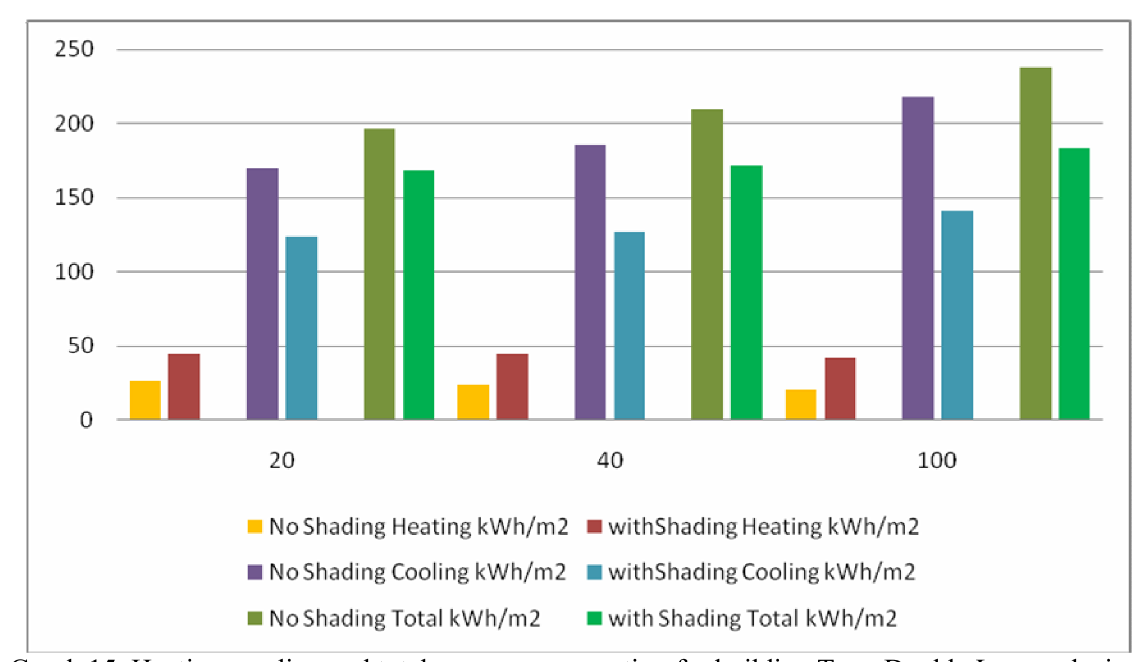
Graph 16 shows heating consumption for Building Two, for cases with different WWRs and different U-values. It also illustrates the difference between heating demand for both shaded and un-shaded cases.

It was found that heating demand can be lowered by more than **25 percent** for low WWR, and more than **23 percent** for high WWR, when comparing between un-insulated cases and cases achieving the Energy Efficient Building Code minimum requirement of U-value 0.57 $kW/m^2.k$.



	20	40	100
No Shading Heating kWh/m2	26.76071347	24.07249838	20.47607745
No Shading Cooling kWh/m2	169.9123281	185.3103064	217.4762548
Total kWh/m2	196.6730416	209.3828047	237.9523323

Graph 14: Heating, cooling and total energy consumption for building Two, Double Low-e glazing, with no shading. (Author)



Graph 15: Heating, cooling and total energy consumption for building Two, Double Low-e glazing, for shaded and un-shaded cases. (Author)

On the other hand, difference in heating consumption between cases achieving the Energy Efficient Building Code minimum requirement of U-value 0.57 kW/m^2.k, and the Green building guideline U-value requirement of 0.45 kW/m^2.k are very low. Savings can be less than **9 percent** between the previously mentioned cases.

This concludes that it is more feasible to comply with the minimum U-value requirements of the Energy Efficient Building Code of Jordan only, without investing in more than that, for South-East facing buildings.

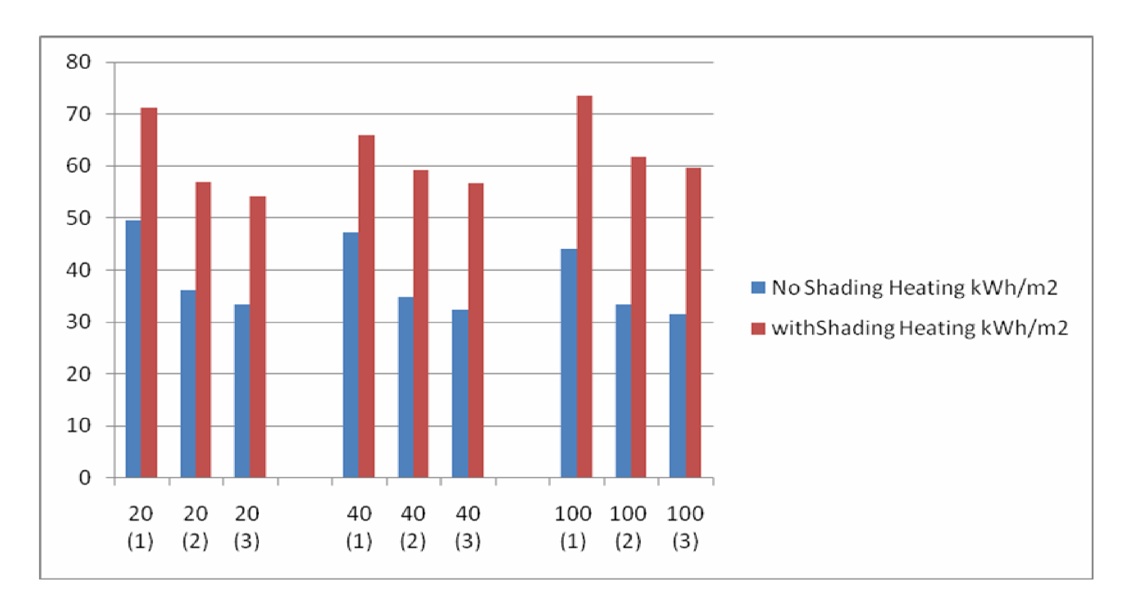
Moreover, Graph 16 shows that shading could increase the heating demand by **45 percent** for high WWR, and by **40 percent** for low WWR. This concludes the use of adjustable shading devices whenever possible. And if not, shading devices should be added to facades with high WWR, in order to lower the high energy demands required for space cooling, despite the fact they negatively affect the heating demand. See Graph 17.

Graph 17 shows cooling consumption for Building Two, for cases with different WWRs and different U-values. It also illustrates the difference between cooling demand for both shaded and un-shaded cases.

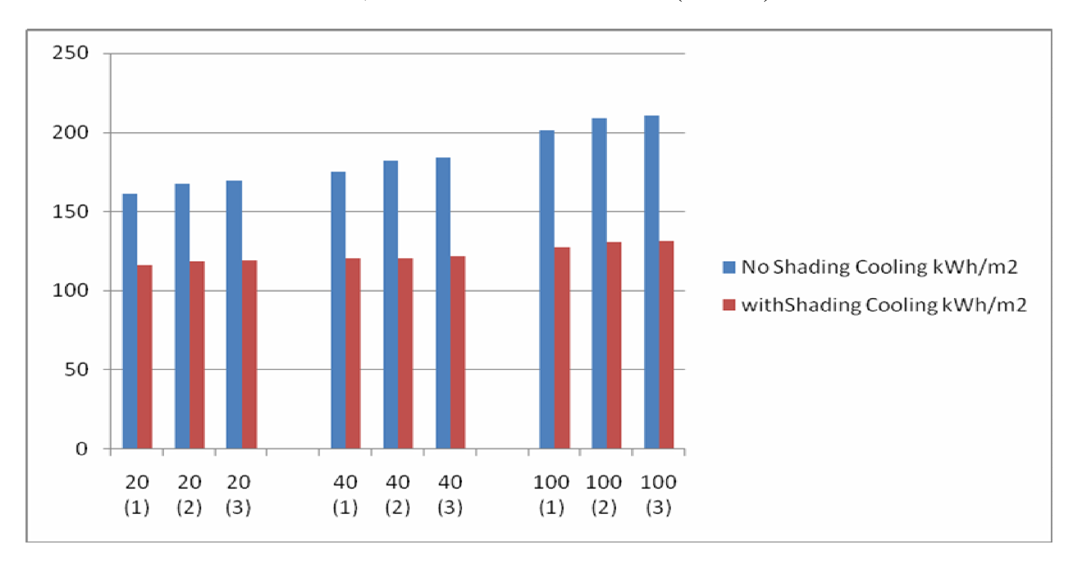
It was found that cooling demand decreases significantly by **41 percent** in energy savings for high WWR. On the other hand, cases with low WWR with shading save more than **30 percent** in cooling demand.

Moreover, cooling demand increases slightly, by less than **4 percent**, when comparing un-insulated cases with cases complying with the minimum U-value requirement. This indication does **NOT** eliminate the importance of complying with minimum U-value required by the Energy Efficient Building Code. Furthermore, it is concluded that South-East facing buildings shading can positively affect the total energy consumption for high and low WWR facades.

Graph 18 indicates heating demand for cases with clear single and double glazing, compared between different WWRs and shaded and un-shaded cases. Results show that more than **15 percent** of the heating demand can be saved when using double glazing compared with single glazing.



Graph 16: Heating consumption for building Two, Single Clear Glazing, for shaded and un-shaded cases, with different U-values*. (Author)



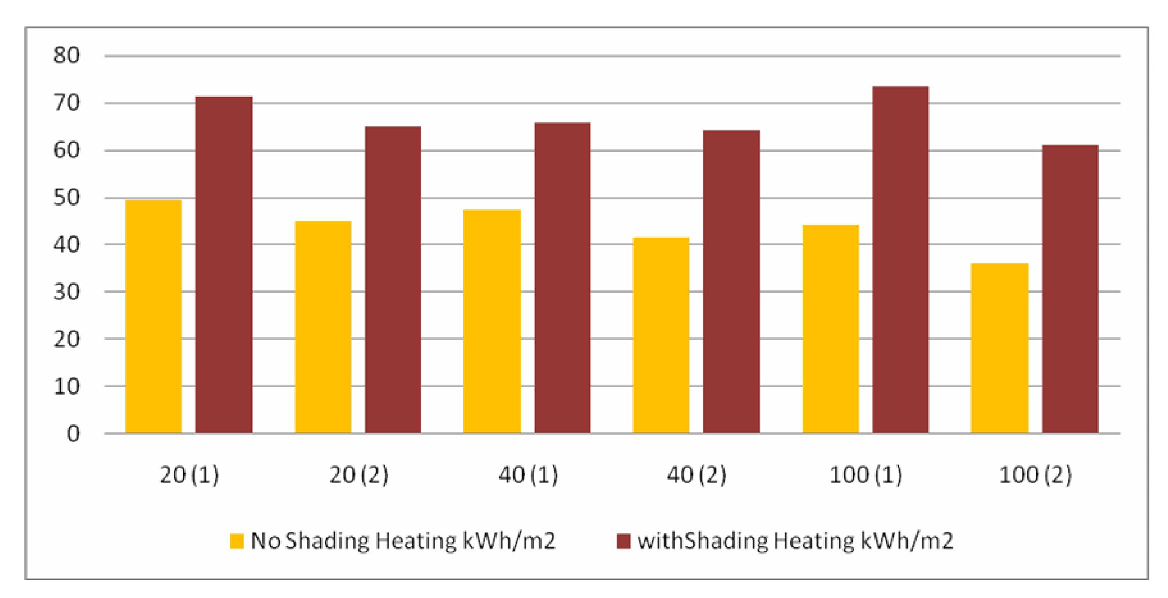
Graph 17: Cooling consumption for building Two, Single Clear Glazing, for shaded and un-shaded cases, with different U-values*. (Author)

* (1) indicates no insulation with 1.8 kW/m^2.k U-values.

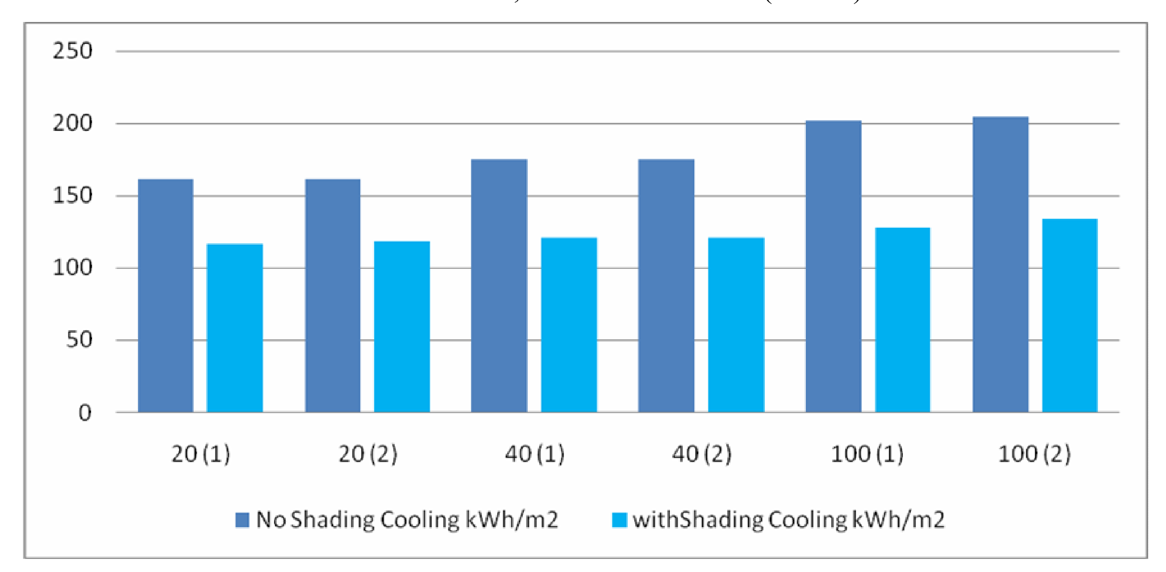
(2) indicates Energy Efficient Building Code insulation requirement with 0.57 kW/m^2.k U-values.

(3) indicates Green building guideline of Jordan insulation requirement with 0.45 kW/m^2.k U-values

However, in Graph 19, which indicates cooling demand for cases with clear single and double glazing compared between different WWRs and shaded and un-shaded cases, it can be concluded that whichever type of glazing is used, it has almost **NO** effect on energy consumption needed for space cooling for buildings with South-East orientation.



Graph 18: Heating consumption for building Two, Single and Double Clear Glazing, for shaded and un-shaded cases, with no insulation*. (Author)



Graph 19: Cooling consumption for building Two, Single and Double Clear Glazing, for shaded and un-shaded cases, with no insulation*. (Author)

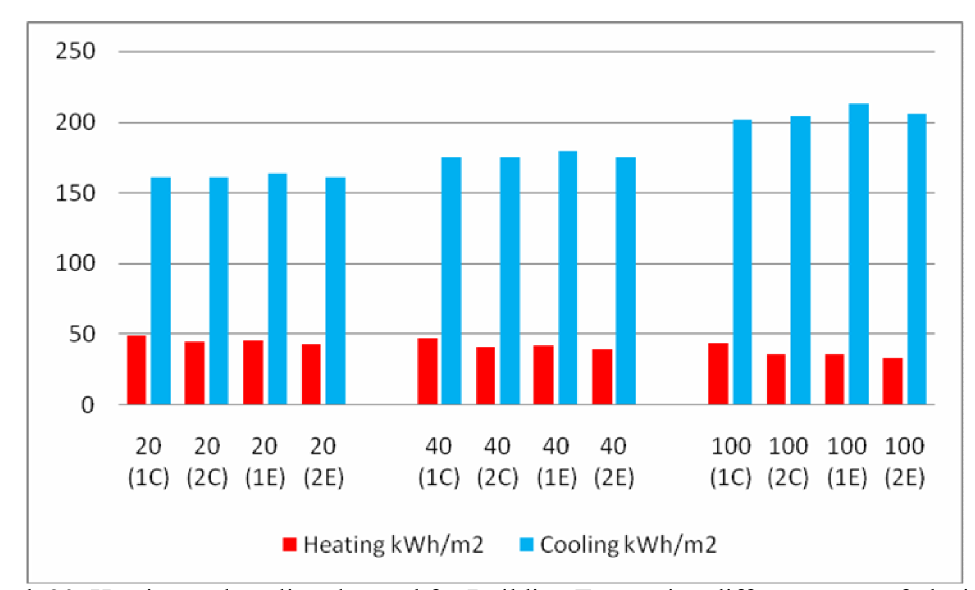
* (1) indicates Clear Single glazing.
(2) indicates Clear Double glazing.

Graph 20 indicates the effect of using Low-e glazing compared with clear glazing, for both single an double glazing, on heating and cooling demands for building Two, South-East Oreintation, with no insulation and no shading.

It was found that using double clear glazing gives almost the same effect of Single low-e glazing in energy consumption used for space heating.

However, in energy consumption used for space cooling, the type of glazing almost have no effect of savings for low WWR facades. On the other hand, for facades with high WWR, it is recommended **NOT** to use single low-e glazing, and recommended to use double clear or Low-e glazing instead.

Graph 21 shows heating, cooling and total energy consumption when using adjustable shading devices in facades with double low-e glazing, where shading devices are only ON when they are needed, i.e. in the summer season. Graph 22 shows the same paremeters but with no shading.

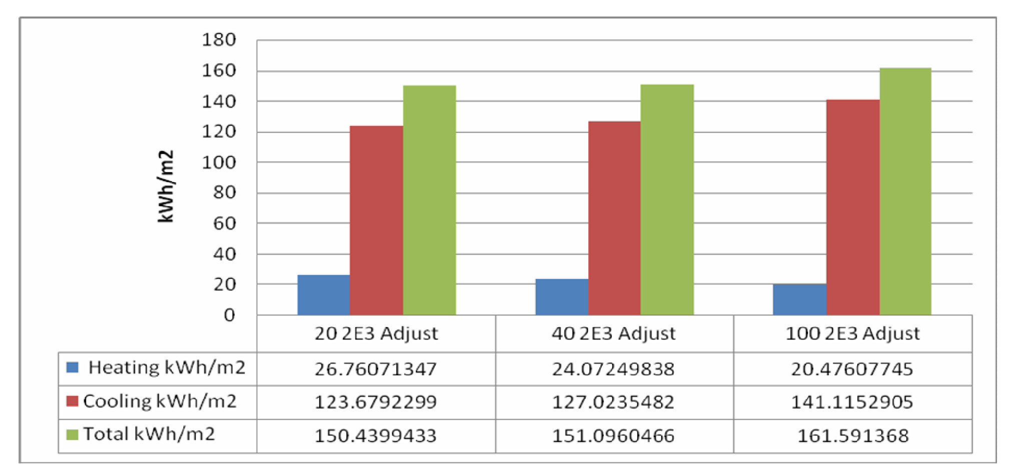


Graph 20: Heating and cooling demand for Building Two, using different types of glazing.*
(Author)

* (1C) indicates Single Clear Glazing
(2C) indicates Double Clear Glazing
(1E) indicates Single Low-e Glazing
(2E) indicates Double Low-e Glazing

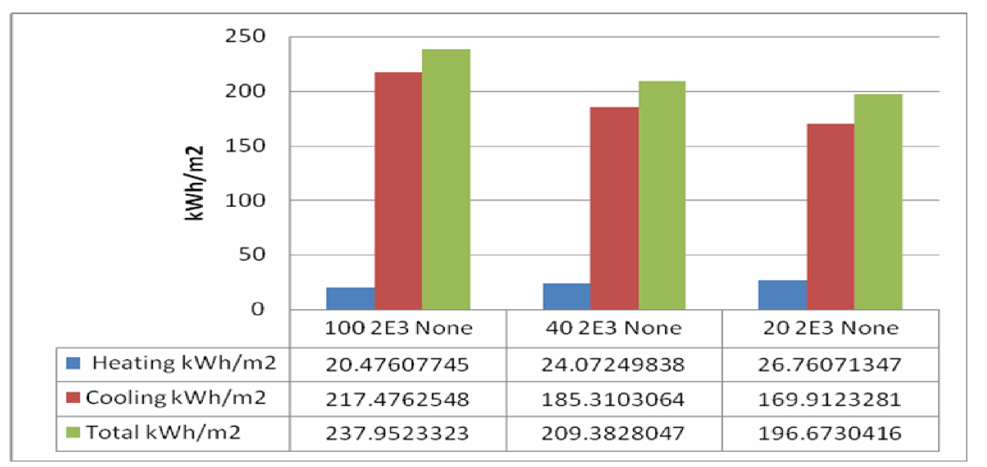
When comparing graph 21 with graph 22 for building Two, the South-East facing building, it was found that energy needed for space heating is still the same for both cases, indicating the use of un-shaded façade in winter. Moreover, when using adjustable shading in the summer. Graph 21 shows that cooling demand has been lowered by **35 percent** for high WWR in comparison with the un-shaded case, leading to a lower value of total energy consumption reaching saving of **32 percent** for high WWR.

However, as mentioned earlier, the use of adjustable shading is more expensive than using fixed external shading. This concludes, that unless nessecary, adjustable shading is most recommended to be used for buildings with high WWR facades, and not to be used for facades with low WWR.



	20 2E3 Adjust	40 2E3 Adjust	100 2E3 Adjust
Heating kWh/m2	26.76071347	24.07249838	20.47607745
Cooling kWh/m2	123.6792299	127.0235482	141.1152905
Total kWh/m2	150.4399433	151.0960466	161.591368

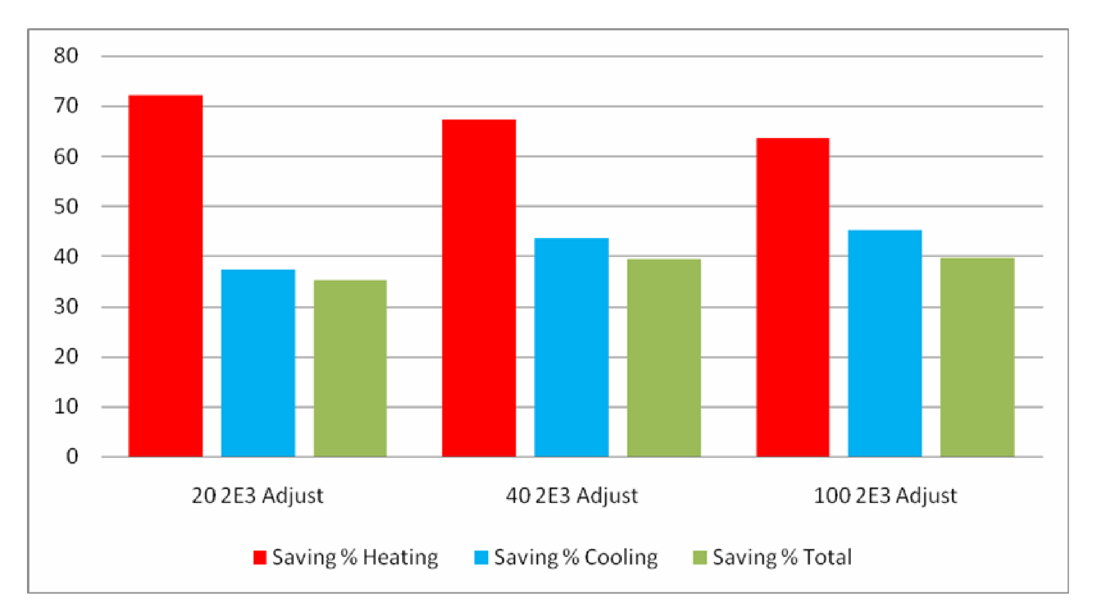
Graph 21: Heating, cooling and total energy consumption for building Two, Double Low-e glazing, with adjustable shading (Author)



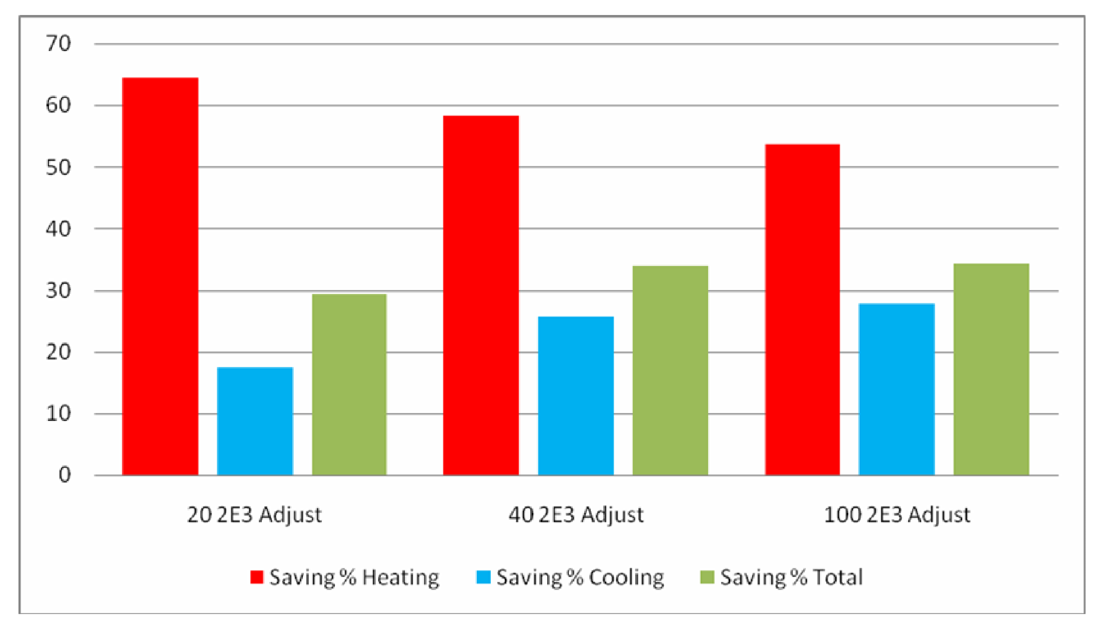
	100 2E3 None	40 2E3 None	20 2E3 None
Heating kWh/m2	20.47607745	24.07249838	26.76071347
Cooling kWh/m2	217.4762548	185.3103064	169.9123281
Total kWh/m2	237.9523323	209.3828047	196.6730416

Graph 22: Heating, cooling and total energy consumption for building Two, Double Low-e glazing, with NO shading (Author)

Graph 23 illustrates savings (in percentage) in heating, cooling and total energy consumption for Building Two when using adjustable shading devices and double Low-e glazing for un-insulated building envelope, compared with worst cases results. See table (59) However, graph 24 shows savings for the same parameters but in comparison with the results of the Base case.



Graph 23: Savings (in percentage) in heating, cooling and total energy consumption when using djustable shading devices in comparison with worst case senario, for Building Two, SE. (Author)



Graph 24: Savings (in percentage) in heating, cooling and total energy consumption when using djustable shading devices in comparison with Base case, for Building Two, SE. (Author)

Table (59) summeries the energy consumption results of the simulation of Building Two, the South-East Orientation, and savings compared with worst case senarios and savings compared with base case design senario for the following:

1) **Base case**
2) **Optimum cases (with adjustable shading devices)**
3) **Best cases**
4) **Worst cases**

Table (60) signifies the descending order of design senarios for Building Two, the South-East Orientation, from the best case recommended for South-East Facing buildings, to the worst case design senario, which should be forbiddened in South-East facing Buildings.

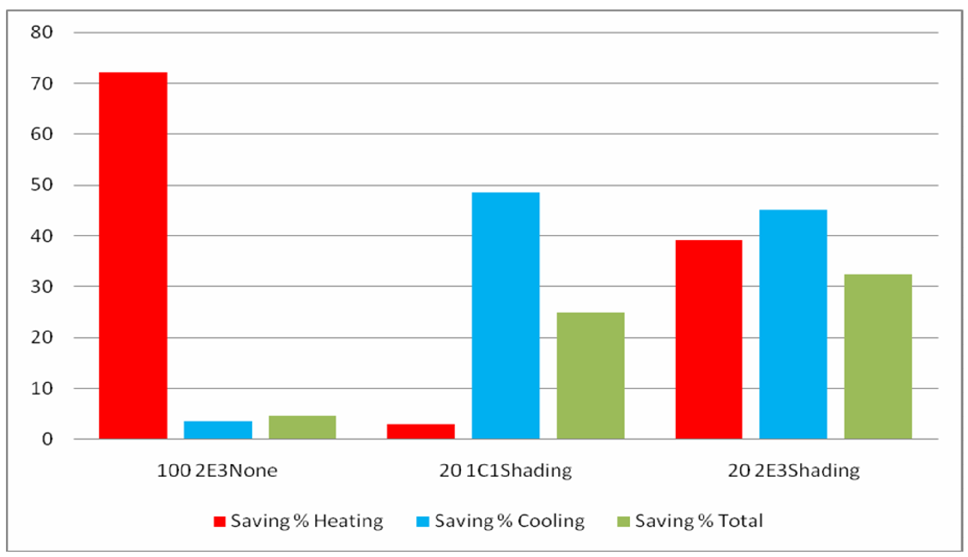
Graph (25) illustrates savings (in percentage) in heating, cooling and total energy consumption for Building Two when using best case senarios, compared with results of worst cases of the research. See table (59). However, graph 26 shows savings for the same parameters but in comparison with the results of the Base case design senario.

Table 59: Summary of results for Building Two, South-East Orientation (Author)

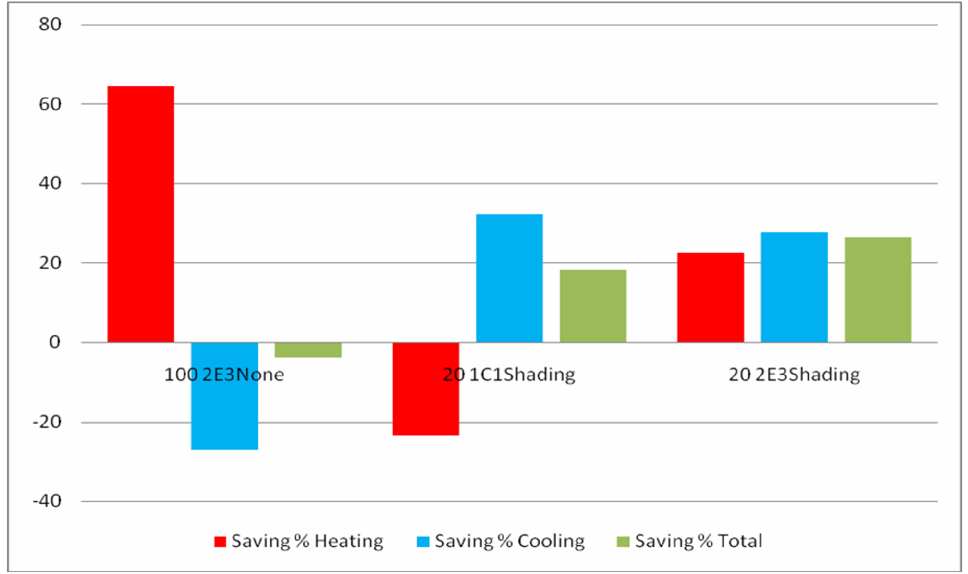
	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2	Compared with worst			Compared with Base		
				Saving% heating	Saving% cooling	Saving % total	Saving% heating	Saving% cooling	Saving % total
Base	57.70	171.12	228.83	21.48	24.07	8.26	0	0	0
Optimum									
100 2E3 Adjust	20.47	141.11	161.59	72.13	37.38	35.21	64.51	17.53	29.38
40 2E3 Adjust	24.07	127.02	151.09	67.24	43.63	39.42	58.28	25.76	33.96
20 2E3 Adjust	26.76	123.68	150.44	63.58	45.12	39.68	53.62	27.72	34.25
Best									
100 2E3None	20.47	217.47	237.95	72.13	3.50	4.60	64.51	-27.08	-3.98
20 1C1Shading	71.22	116.01	187.235	3.1	48.52	24.93	-23.41	32.20	18.17
20 2E3Shading	44.71	123.67	168.39	39.15	45.12	32.49	22.51	27.724	26.41
Worst									
100 1C1Shading	73.49	127.77	201.26	0	43.30	19.31	-27.35	25.32	12.04
100 1E3None	23.17	225.37	248.55	68.46	0	0.35	59.83	-31.70	-8.61
100 1E1None	36.42	213.01	249.44	50.43	5.48	0	36.87	-24.48	-9.01

Table 60: Descending Order of Design case scenarios for Building Two, South-East Orientation, from Best to worst (Author)

	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2
20 2E3 Adjust	26.76	123.68	150.44
40 2E3 Adjust	24.07	127.02	151.09
100 2E3 Adjust	20.47	141.11	161.59
20 2E3Shading	44.71	123.67	168.39
20 1C1Shading	71.22	116.01	187.235
100 2E3None	20.47	217.47	237.95
100 1E3None	23.17	225.37	248.55
100 1E1None	36.42	213.01	249.44



Graph 25: Savings (in percentage) in heating, cooling and total energy consumption when using best case design senario in comparison with worst case senario, Building Two, SE. (Author)



Graph 26: Savings (in percentage) in heating, cooling and total energy consumption when using best case design senario in comparison with base case senario, Building Two, SE. (Author)

4-4 Building Three, North-West Orientation:

Graph 27 shows the classification of energy consumption in building Three, the North-West facing building.

It was found that the higher the WWR, the higher the energy demand, regardless of type of glazing or insulation.

In addition, it was found that more than **75 percent** of the energy consumption is dedicated for space cooling and **25 percent** goes to space heating. This shows that cooling demand is more important to rationalize than heating demand, although it is important to look at ways for lowering heating loads.

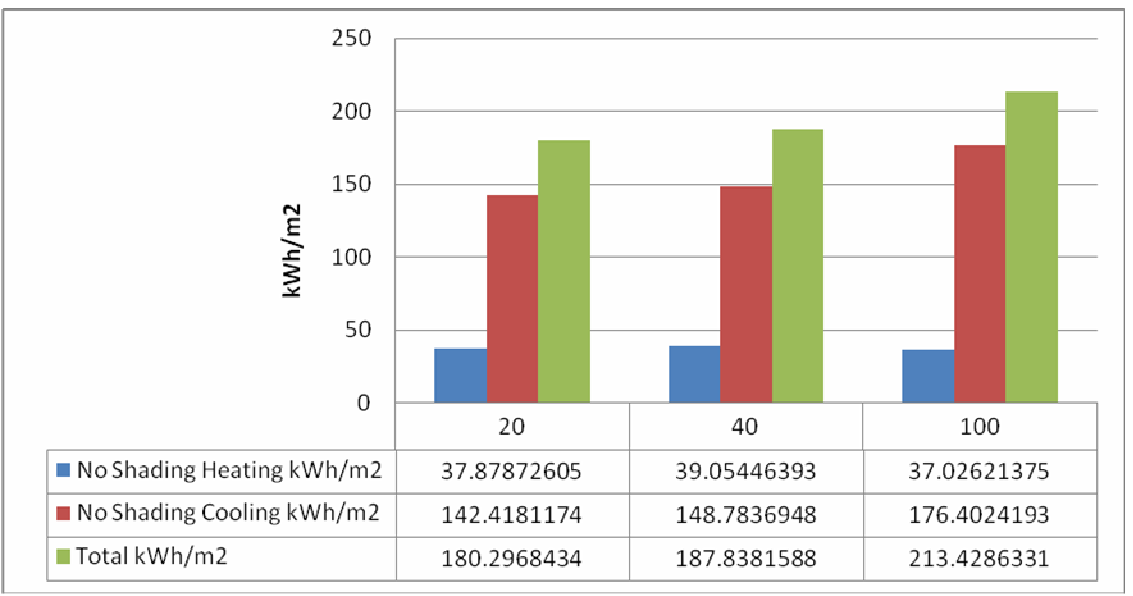
Graph 28 shows heating, cooling and total energy consumption for Building Three, the North- West facing building, for shaded and un-shaded cases, when using double low-e glazing.

It is concluded that shading has minimum negative effect on heating demand by increasing it for **11 percent** at the most. On the other hand, **energy saving** for cooling **increases** reaching **15 percent** for shaded cases compared with un-shaded cases.

Graph 28 also indicates that the higher the WWR, the more positive effect shading devices offer. However the percentage of saving is not that high, which means that it is NOT important to invest in shading devices for buildings which are North-West oriented, regardless of the WWR.

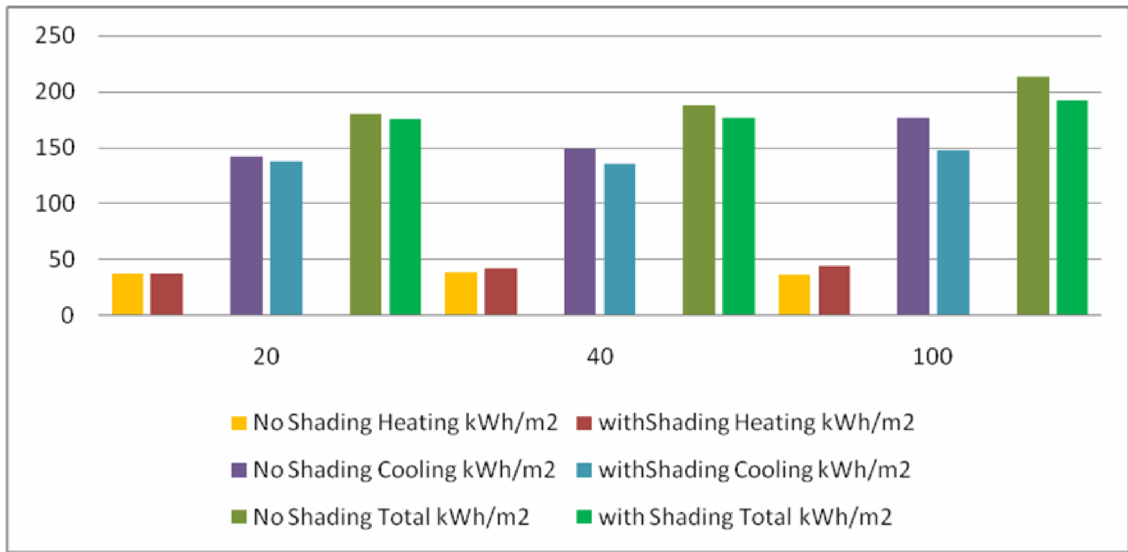
Graph 29 shows heating consumption for Building Three, for cases with different WWRs and different U-values. It also illustrates the difference between heating demand for both shaded and un-shaded cases.

It was found that heating demand can be lowered by more than **19 percent** for low WWR, and more than **15 percent** for high WWR, when comparing between un-insulated cases and cases achieving the Energy Efficient Building Code minimum requirement of U-value 0.57 $kW/m^2.k$.



	20	40	100
No Shading Heating kWh/m2	37.87872605	39.05446393	37.02621375
No Shading Cooling kWh/m2	142.4181174	148.7836948	176.4024193
Total kWh/m2	180.2968434	187.8381588	213.4286331

Graph 27: Heating, cooling and total energy consumption for building Three, Double Low-e glazing, with no shading. (Author)



Graph 28: Heating, cooling and total energy consumption for building Three, Double Low-e glazing, for shaded and un-shaded cases. (Author)

On the other hand, difference in heating consumption between cases achieving the Energy Efficient Building Code minimum requirement of U-value 0.57 $kW/m^2.k$, and the Green building guideline U-value requirement of 0.45 $kW/m^2.k$ are very low. Savings can be less than **4 percent** between the previously mentioned cases.

This concludes that it is more feasible to comply with the minimum U-value requirements of the Energy Efficient Building Code of Jordan only, without investing in more than that, for North-West facing buildings.

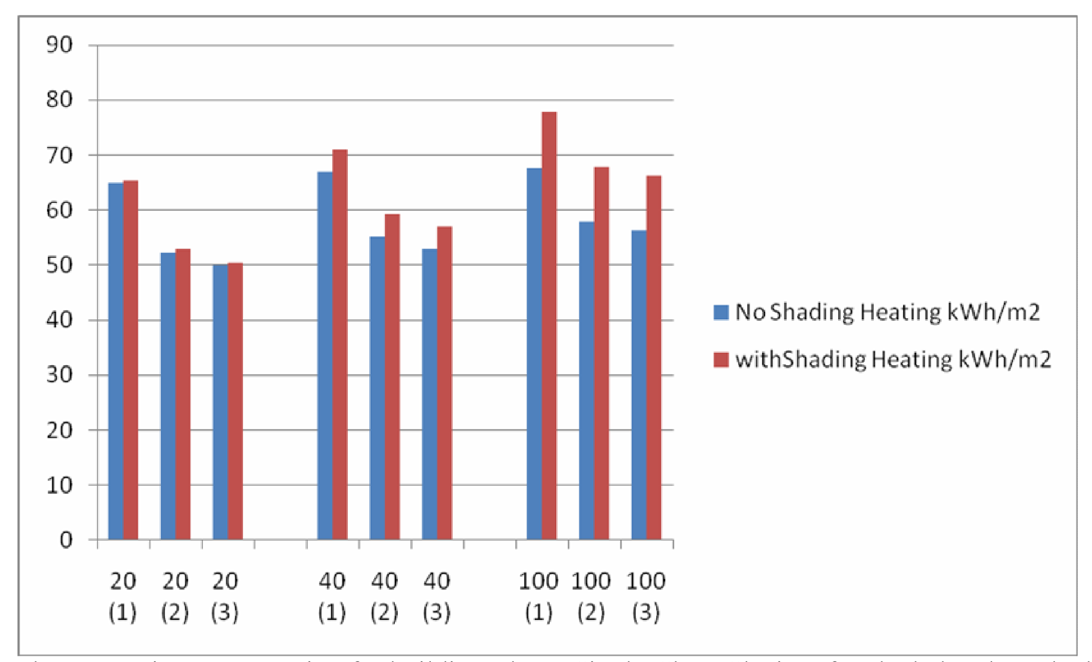
Moreover, Graph 29 shows that shading could increase the heating demand by **14 percent** for high WWR, and by **3 percent** for low WWR.

Graph 30 shows cooling consumption for Building Three, for cases with different WWRs and different U-values. It also illustrates the difference between cooling demand for both shaded and un-shaded cases.

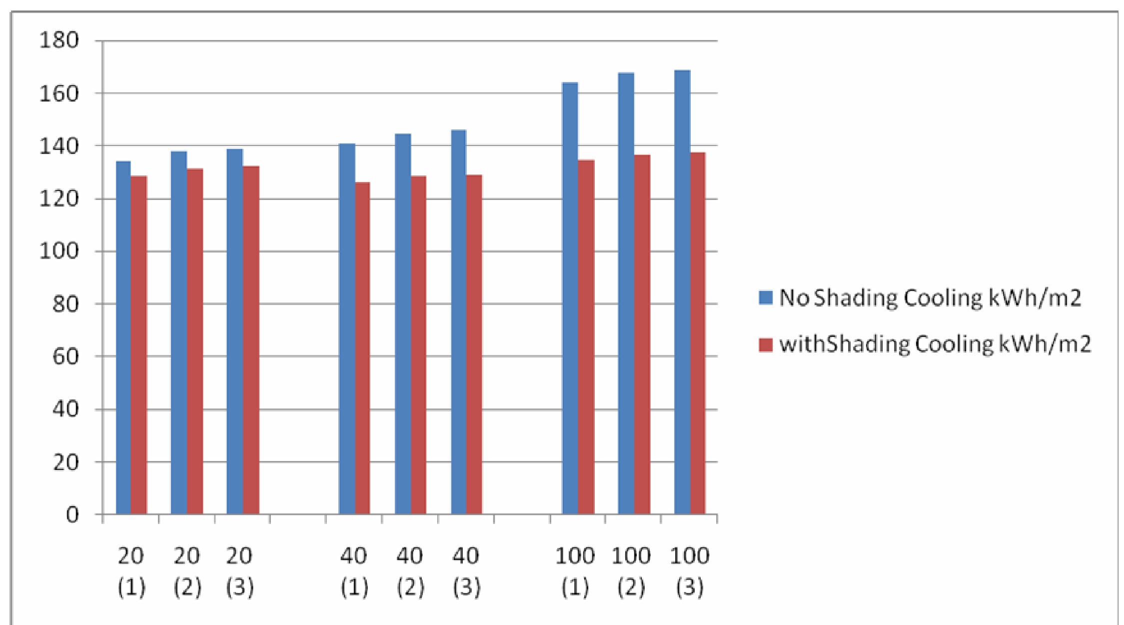
It was found that cooling demand decreases by **18 percent** in energy savings for high WWR. On the other hand, cases with low WWR with shading save less than **5 percent** in cooling demand.

Moreover, cooling demand increases slightly, by less than **3 percent**, when comparing un-insulated cases with cases complying with the minimum U-value requirement. This indication does **NOT** eliminate the importance of complying with minimum U-value required by the Energy Efficient Building Code. Furthermore, it is concluded that North-West facing buildings shading does not contribute to more than **19 percent** saving in total energy consumption, which makes it **NOT** feasible to add external fixed shading devices. The depth of the windows/ openings of 10 cm is enough for the purpose of shading North-West facing facades.

Graph 31 indicates heating demand for cases with clear single and double glazing, compared between different WWRs and shaded and un-shaded cases. Results show that more than **15 percent** of the heating demand can be saved when using double glazing compared with single glazing.



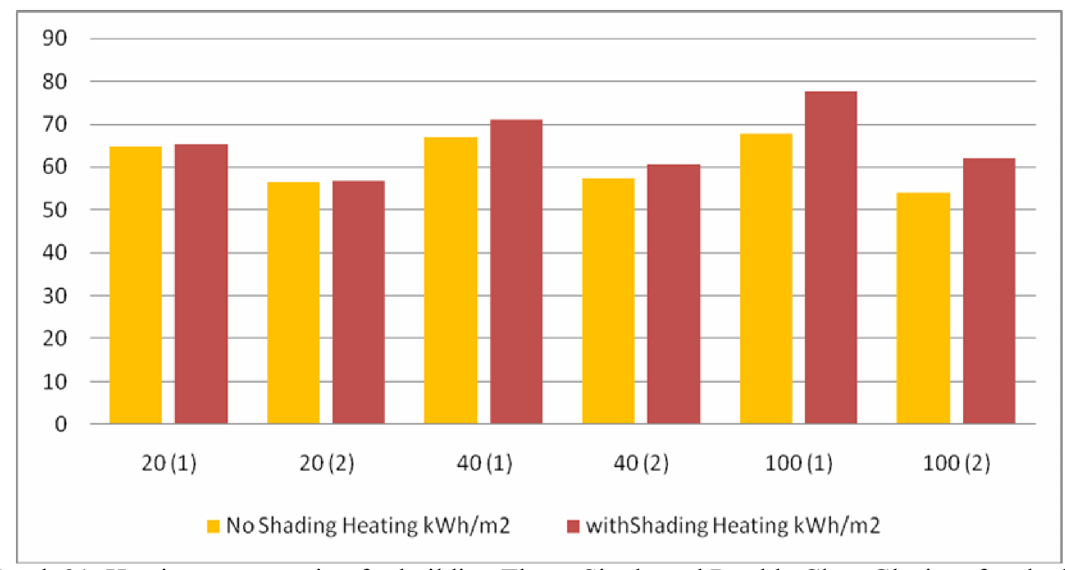
Graph 29: Heating consumption for building Three, Single Clear Glazing, for shaded and un-shaded cases, with different U-values*. (Author)



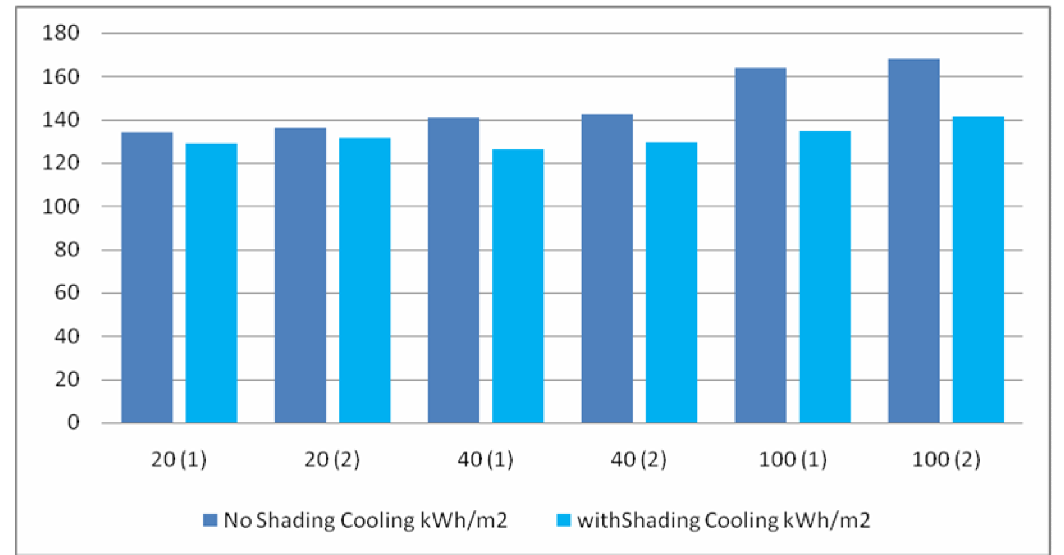
Graph 30: Cooling consumption for building Three, Single Clear Glazing, for shaded and un-shaded cases, with different U-values*. (Author)

* (1) indicates no insulation with 1.8 kW/m^2.k U-values.
(2) indicates Energy Efficient Building Code insulation requirement with 0.57 kW/m^2.k U-values.
(3) indicates Green building guideline of Jordan insulation requirement with 0.45 kW/m^2.k U-values

However, in Graph 32, which indicates cooling demand for cases with clear single and double glazing compared between different WWRs and shaded and un-shaded cases, it can be concluded that whichever type of glazing is used, it has almost **NO** effect on energy consumption needed for space cooling for buildings with North-West orientation



Graph 31: Heating consumption for building Three, Single and Double Clear Glazing, for shaded and un-shaded cases, with no insulation*. (Author)



Graph 32: Cooling consumption for building Three, Single and Double Clear Glazing, for shaded and un-shaded cases, with no insulation*. (Author)

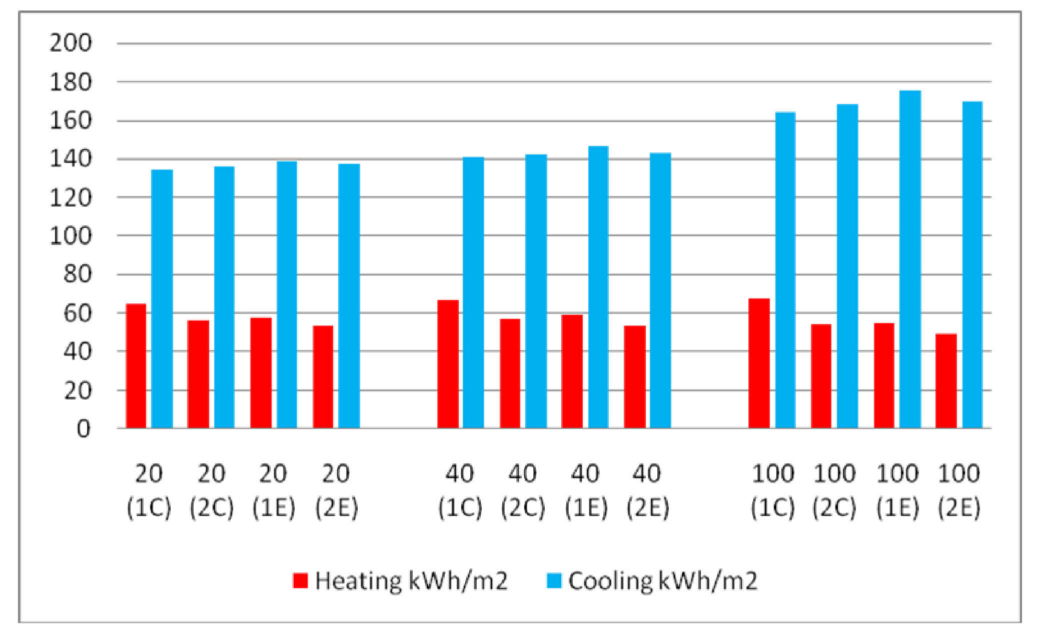
* (1) indicates Clear Single glazing.
(2) Indicates Clear Double glazing

Graph 33 indicates the effect of using Low-e glazing compared with clear glazing, for both single and double glazing, on heating and cooling demands for building Three, North-West Oreintation, with no insulation and no shading.

It was found that using double clear glazing gives almost the same effect of Single low-e glazing in energy consumption used for space heating.

However, in energy consumption used for space cooling, the type of glazing almost have no effect of savings for low WWR facades. On the other hand, for facades with high WWR, it is recommended **NOT** to use single low-e glazing, and recommended to use double Low-e glazing instead.

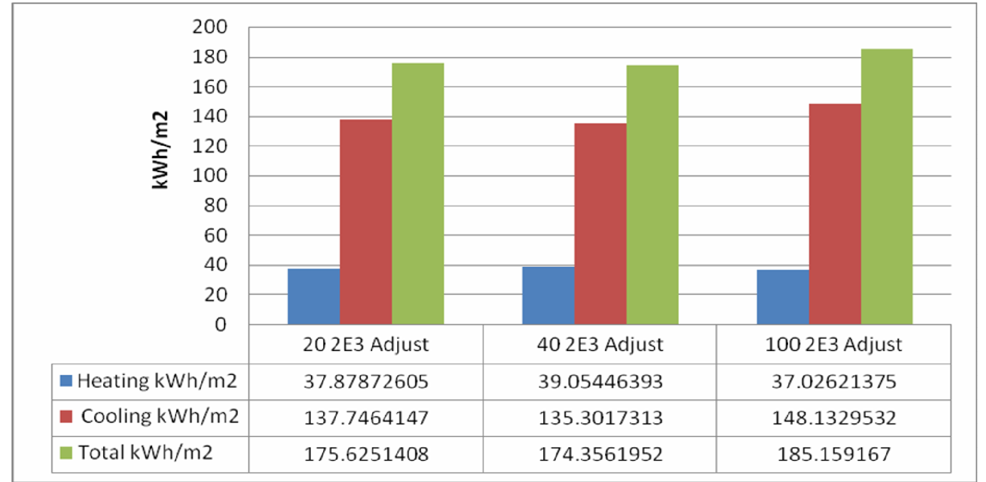
Graph 34 shows heating, cooling and total energy consumption when using adjustable shading devices in facades with double low-e glazing, where shading devices are only ON when they are needed, i.e. in the summer season. Graph 35 shows the same paremeters but with no shading.



Graph 33: Heating and cooling demand for Building Three, using different types of glazing.*
(Author)

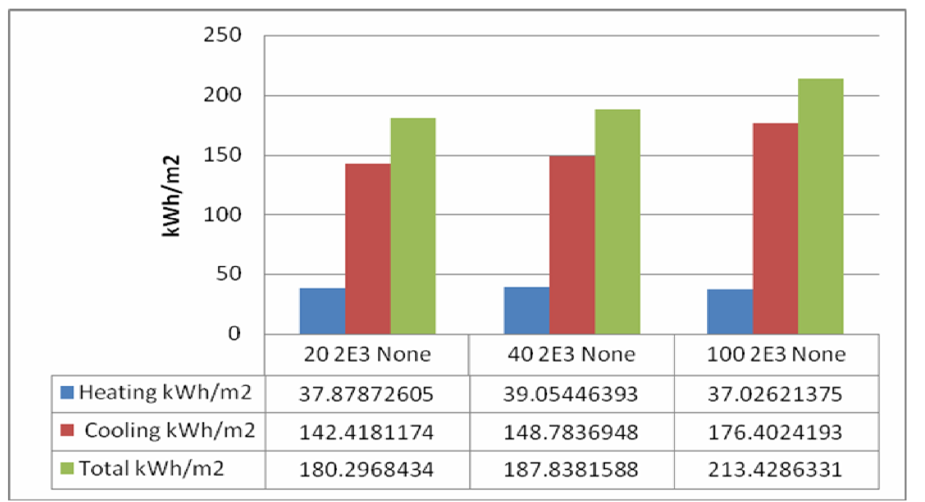
* (1C) indicates Single Clear Glazing
(2C) indicates Double Clear Glazing
(1E) indicates Single Low-e Glazing
(2E) indicates Double Low-e Glazing

When comparing graph 34 with graph 35 for building Three, the North-West facing building, it was found that energy needed for space heating is still the same for both cases, indicating the use of un-shaded façade in winter. Moreover, when using adjustable shading in the summer. Graph 34 shows that cooling demand has been lowered by **16 percent** for high WWR in comparison with the un-shaded case, leading to a lower value of total energy consumption reaching saving of **13 percent** for high WWR. However, the use of adjustable shading is more expensive than using fixed external shading. This concludes, that based on the low saving percentage adjustable and fixed shading devices offer, it is **NOT** recommended to invest in North-West facing buildings, regardless of façade WWR.



	20 2E3 Adjust	40 2E3 Adjust	100 2E3 Adjust
Heating kWh/m2	37.87872605	39.05446393	37.02621375
Cooling kWh/m2	137.7464147	135.3017313	148.1329532
Total kWh/m2	175.6251408	174.3561952	185.159167

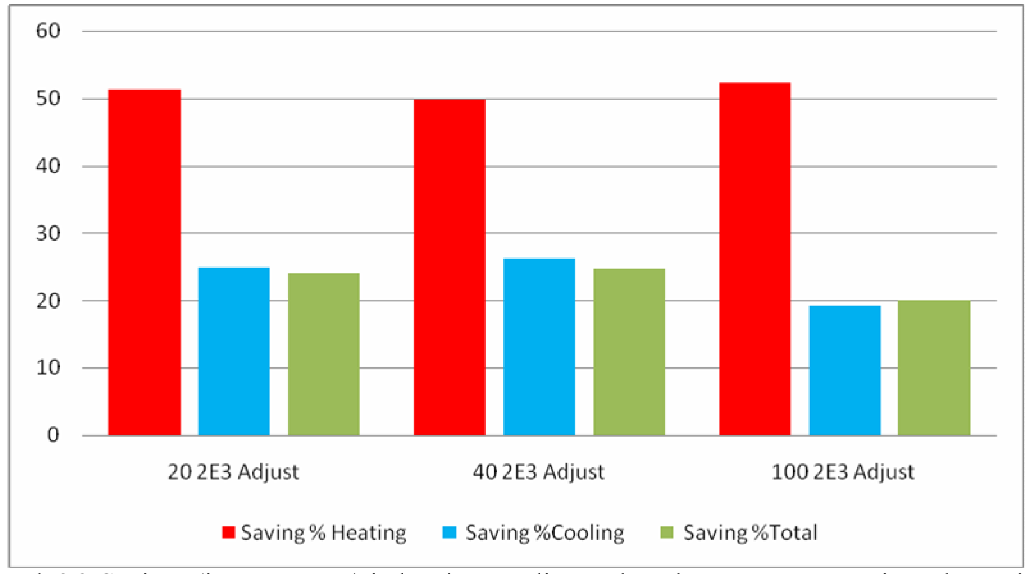
Graph 34: Heating, cooling and total energy consumption for building Three, Double Low-e glazing, with adjustable shading. (Author)



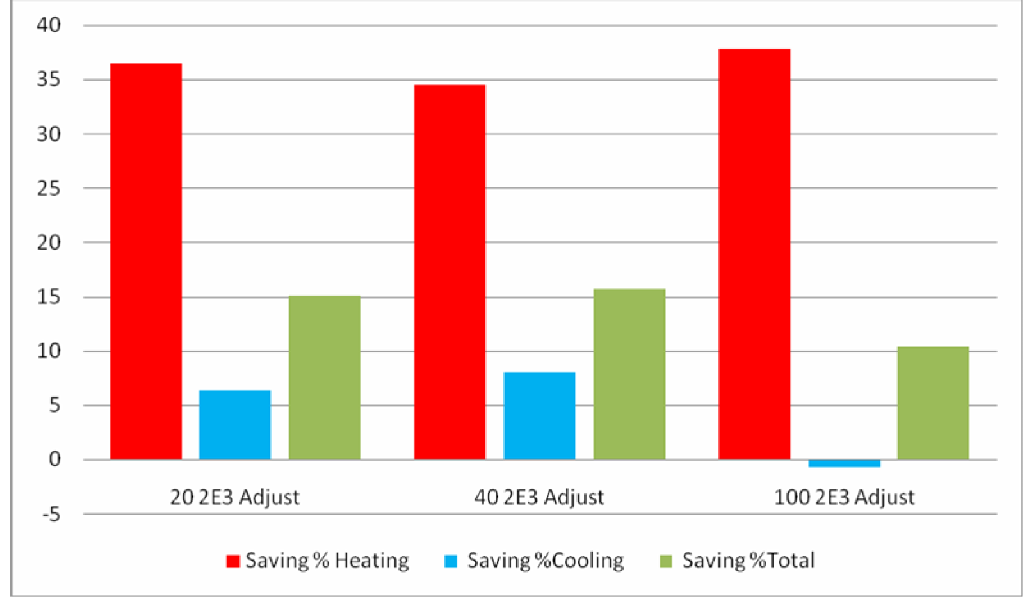
	20 2E3 None	40 2E3 None	100 2E3 None
Heating kWh/m2	37.87872605	39.05446393	37.02621375
Cooling kWh/m2	142.4181174	148.7836948	176.4024193
Total kWh/m2	180.2968434	187.8381588	213.4286331

Graph 35: Heating, cooling and total energy consumption for building Three, Double Low-e glazing, with NO shading. (Author)

Graph 36 illustrates savings (in percentage) in heating, cooling and total energy consumption for Building Three when using adjustable shading devices and double Low-e glazing for un-insulated building envelope, compared with worst cases results. See table (61) However, graph 37 shows savings for the same parameters but in comparison with the results of the Base case.



Graph 36: Savings (in percentage) in heating, cooling and total energy consumption when using adjustable shading devices in comparison with worst case senario, for Building Three, NW. (Author)



Graph 37: Savings (in percentage) in heating, cooling and total energy consumption when using adjustable shading devices in comparison with base case senario, for Building Three, NW. (Author)

Table (61) summeries the energy consumption results of the simulation of Building Three, the North-West Orientation, and savings compared with worst case senarios and savings compared with base case design senario for the following:

1) **Base case**
2) **Optimum cases (with adjustable shading devices)**
3) **Best cases**
4) **Worst cases**

Table (62) signifies the descending order of design senarios for Building Three, the North-West Orientation, from the best case recommended for North-West Facing buildings, to the worst case design senario, which should be forbiddened in North-West facing Buildings.

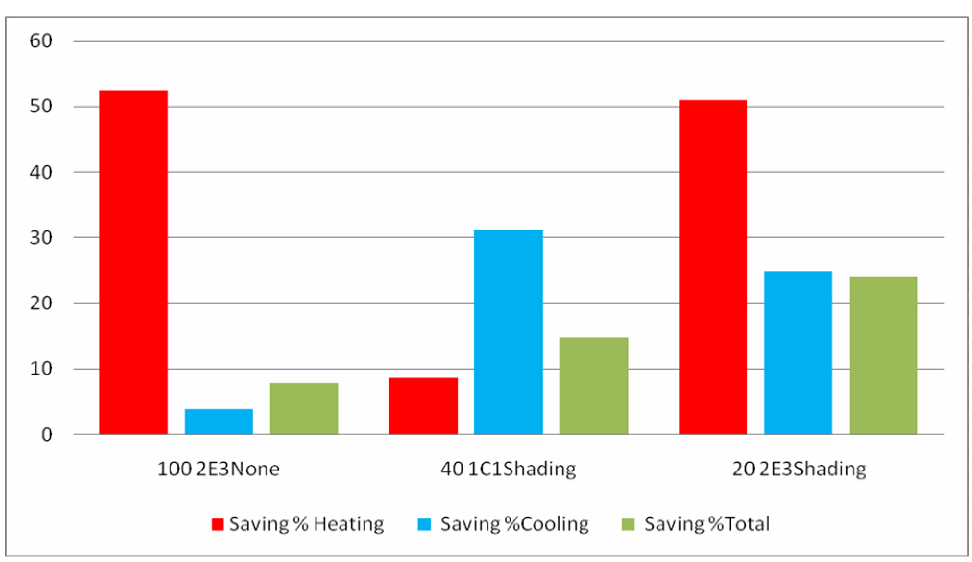
Graph 38 illustrates savings (in percentage) in heating, cooling and total energy consumption for Building Three when using best case senarios, compared with results of worst cases of the research. See table (61). However, graph 39 shows savings for the same parameters but in comparison with the results of the Base case design senario.

Table 61: Summary of results for Building Three, North-West Orientation (Author)

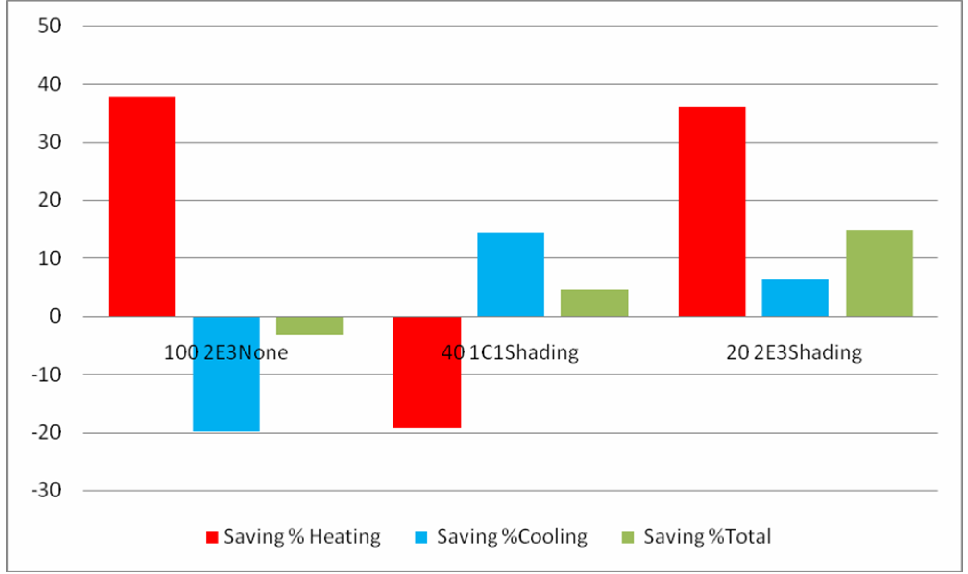
	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2	Compared with worst			Compared with Base		
				Saving% heating	Saving% cooling	Saving % total	Saving% heating	Saving% cooling	Saving % total
Base	59.58	147.09	206.68	23.33	19.74	10.72	0	0	0
Optimum									
20 2E3 Adjust	37.87	137.74	175.62	51.27	24.84	24.13	36.42	6.35	15.02
40 2E3 Adjust	39.05	135.30	174.35	49.76	26.18	24.68	34.45	8.02	15.63
100 2E3 Adjust	37.02	148.13	185.15	52.37	19.18	20.01	37.85	-0.70	10.41
Best									
100 2E3 None	37.02	176.4	213.42	52.37	3.75	7.80	37.85	-19.92	-3.26
40 1C1Shading	71.11	126.12	197.24	8.52	31.18	14.79	-19.36	14.25	4.56
20 2E3 Shading	38.07	137.74	175.82	51.02	24.84	24.05	36.09	6.35	14.92
Worst									
100 1C1 Shading	77.74	134.55	212.30	0	26.58	8.29	-30.48	8.52804	-2.71
100 1E3 None	42.72	183.28	226.01	45.04	0	2.36	28.28	-24.60	-9.35
100 1C1 None	67.70	163.79	231.50	12.91	10.63	0	-13.64	-11.34	-12.01

Table 62: Descending Order of Design case scenarios for Building Three, North-West Orientation, from Best to worst (Author)

	Heating kWh/m²	Cooling kWh/m²	Total kWh/m²
40 2E3 None	39.05	135.30	174.35
20 2E3 Adjust	37.87	137.74	175.62
20 2E3 Shading	38.07	137.74	175.82
100 2E3 Adjust	37.02	148.13	185.15
40 1C1 Shading	71.11	126.12	197.24
100 1C1 Shading	77.74	134.55	212.30
100 1E3 None	42.72	183.28	226.01
100 1C1 None	67.70	163.79	231.50



Graph 38: Savings (in percentage) in heating, cooling and total energy consumption when using best case design senario in comparison with worst case senario, Building Three, NW. (Author)



Graph 39: Savings (in percentage) in heating, cooling and total energy consumption when using best case design senario in comparison with base case senario, Building Three, NW. (Author)

4-5 Building Four, North-East Orientation:

Graph 40 shows the classification of energy consumption in building Four, the North-East facing building.

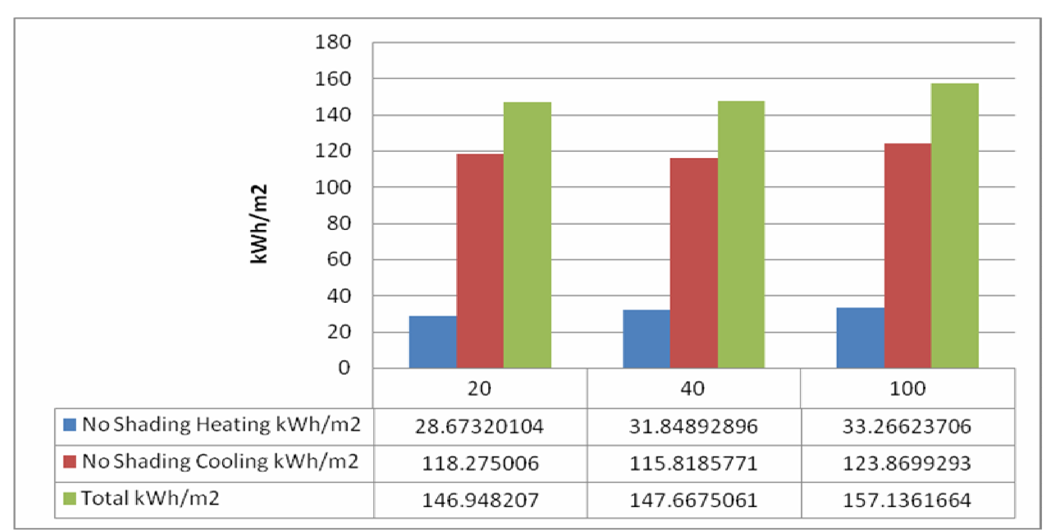
It was found that the higher the WWR, the higher the energy demand, regardless of type of glazing or insulation.

In addition, it was found that more than **75 percent** of the energy consumption is dedicated for space cooling and **25 percent** goes to space heating. This shows that cooling demand is more important to rationalize than heating demand, although it is important to look at ways for lowering heating loads.

Graph 41 shows heating, cooling and total energy consumption for Building Four, the North- East facing building, for shaded and un-shaded cases, when using double low-e glazing. It is concluded that shading has almost NO effect on BOTH heating and cooling demand, which means that it is NOT at all recommended to invest in shading devices for buildings which are North-East oriented, regardless of the WWR.

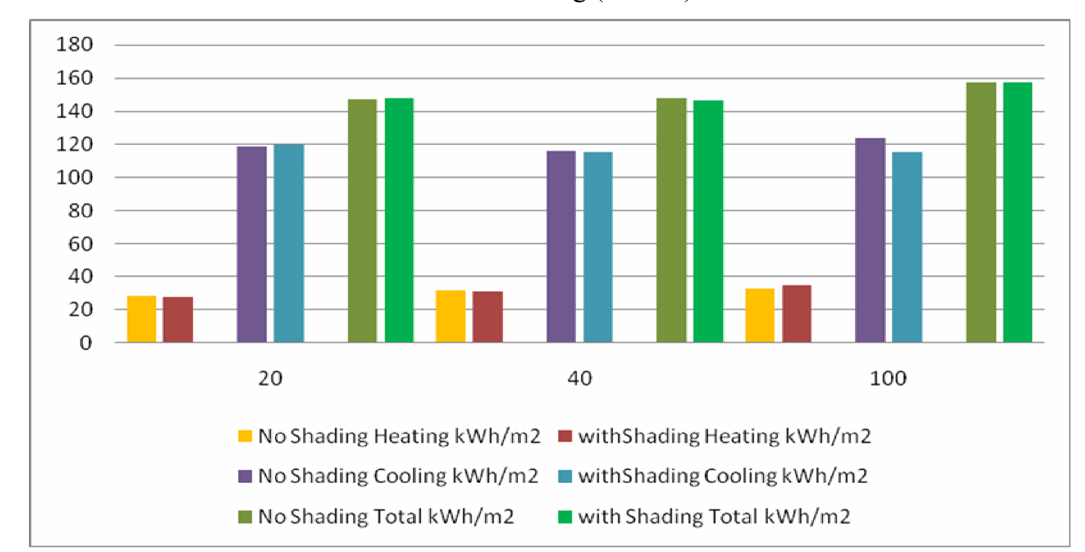
Graph 42 shows heating consumption for Building Four, for cases with different WWRs and different U-values. It also illustrates the difference between heating demand for both shaded and un-shaded cases.

It was found that heating demand can be lowered by more than **25 percent** for low WWR, and more than **16 percent** for high WWR, when comparing between un-insulated cases and cases achieving the Energy Efficient Building Code minimum requirement of U-value 0.57 $kW/m^2.k$



	20	40	100
No Shading Heating kWh/m2	28.67320104	31.84892896	33.26623706
No Shading Cooling kWh/m2	118.275006	115.8185771	123.8699293
Total kWh/m2	146.948207	147.6675061	157.1361664

Graph 40: Heating, cooling and total energy consumption for building Four, Double Low-e glazing, with no shading (Author)



Graph 41: Heating, cooling and total energy consumption for building Four, Double Low-e glazing, for shaded and un-shaded cases (Author)

On the other hand, difference in heating consumption between cases achieving the Energy Efficient Building Code minimum requirement of U-value 0.57 $kW/m^2.k$, and the Green building guideline U-value requirement of 0.45 $kW/m^2.k$ are very low. Savings can be less than **3 percent** between the previously mentioned cases.

This concludes that it is more feasible to comply with the minimum U-value requirements of the Energy Efficient Building Code of Jordan only, without investing in more than that, for North-East facing buildings.

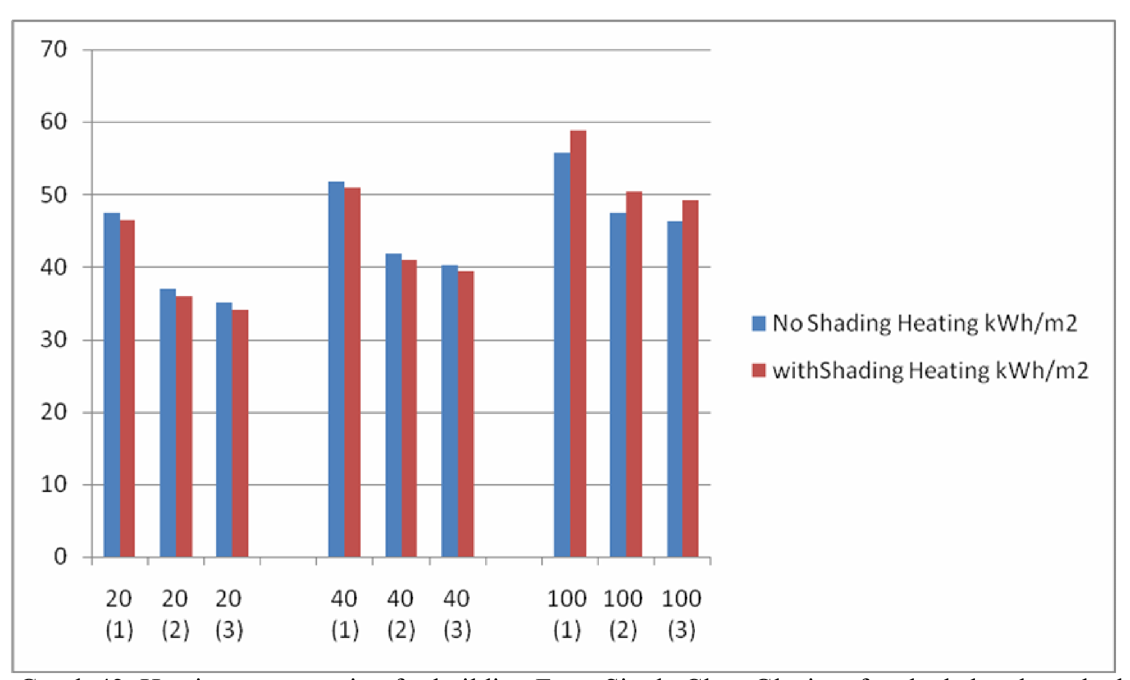
Moreover, Graph 42 shows that shading could increase the heating demand by **4 percent** for high WWR, and lower it by **3 percent** for low WWR.

Graph 43 shows cooling consumption for Building Four, for cases with different WWRs and different U-values. It also illustrates the difference between cooling demand for both shaded and un-shaded cases. It was found that cooling demand decreases by **7 percent** in energy savings for high WWR. On the other hand, cooling demand in cases with low WWR with shading increase by **2 percent.**

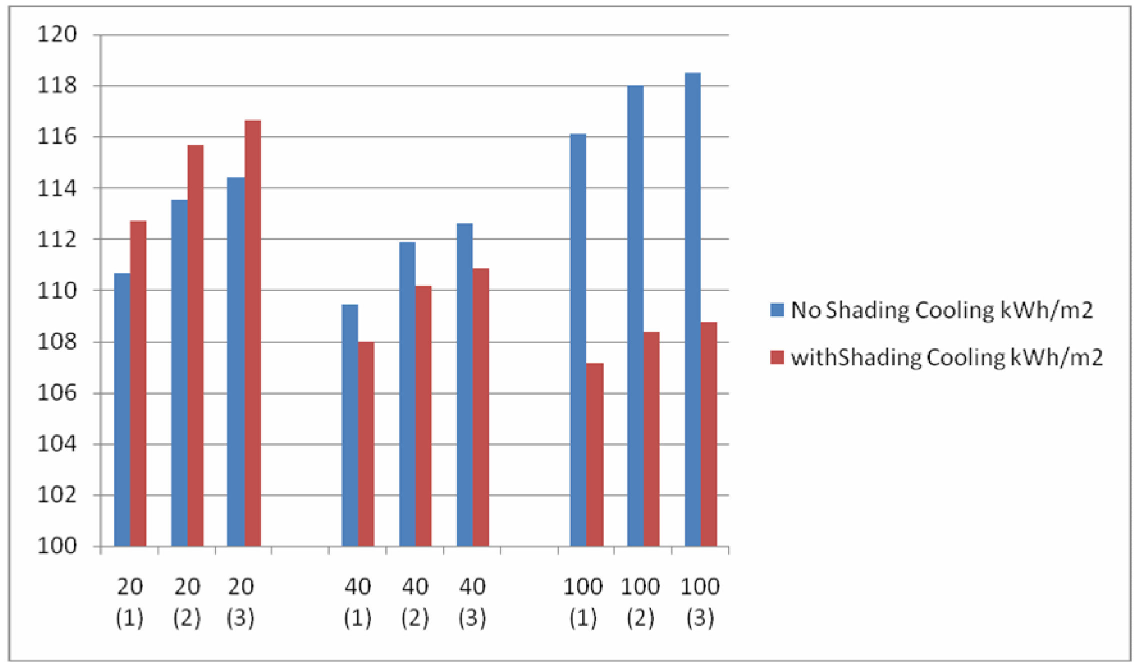
Moreover, cooling demand increases slightly, by less than **3 percent**, when comparing un-insulated cases with cases complying with the minimum U-value requirement. This indication does **NOT** eliminate the importance of complying with minimum U-value required by the Energy Efficient Building Code. Furthermore, it is concluded that North-East facing buildings shading does not contribute to more than **7 percent** saving in total energy consumption, which makes it **NOT** feasible to add external fixed shading devices. The depth of the windows/ openings of 10 cm is enough for the purpose of shading North-East facing facades.

Graph 44 indicates heating demand for cases with clear single and double glazing, compared between different WWRs and shaded and un-shaded cases. Results show that more than **15 percent** of the heating demand can be saved when using double glazing compared with single glazing

However, in Graph 45, which indicates cooling demand for cases with clear single and double glazing compared between different WWRs and shaded and un-shaded cases, it can be concluded that whichever type of glazing is used, it has almost **NO** effect on energy consumption needed for space cooling for buildings with North-East orientation



Graph 42: Heating consumption for building Four, Single Clear Glazing, for shaded and un-shaded cases, with different U-values*. (Author)

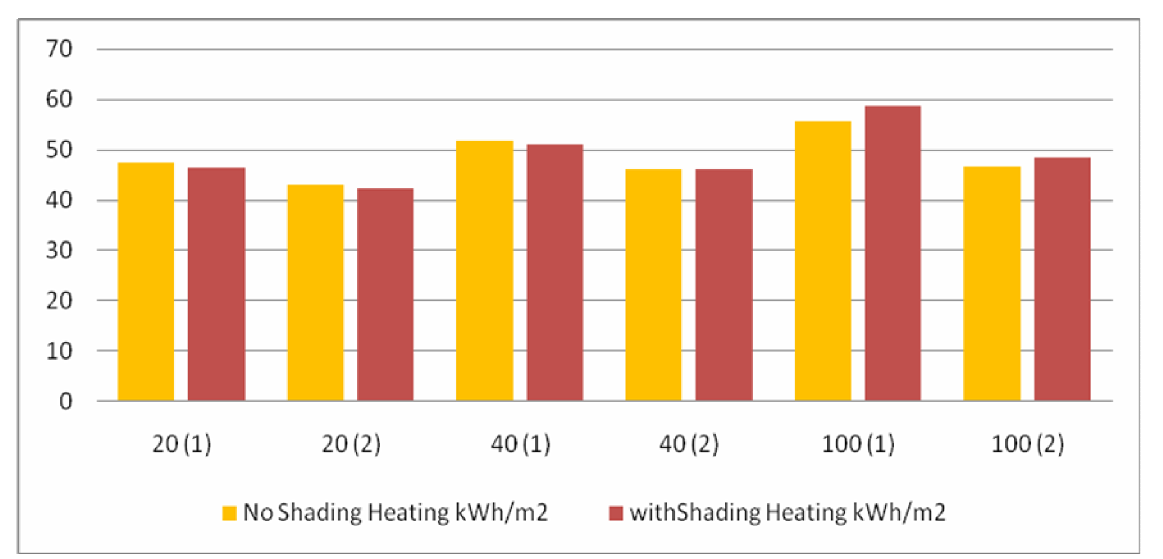


Graph 43: Cooling consumption for building Four, Single Clear Glazing, for shaded and un-shaded cases, with different U-values*. (Author)

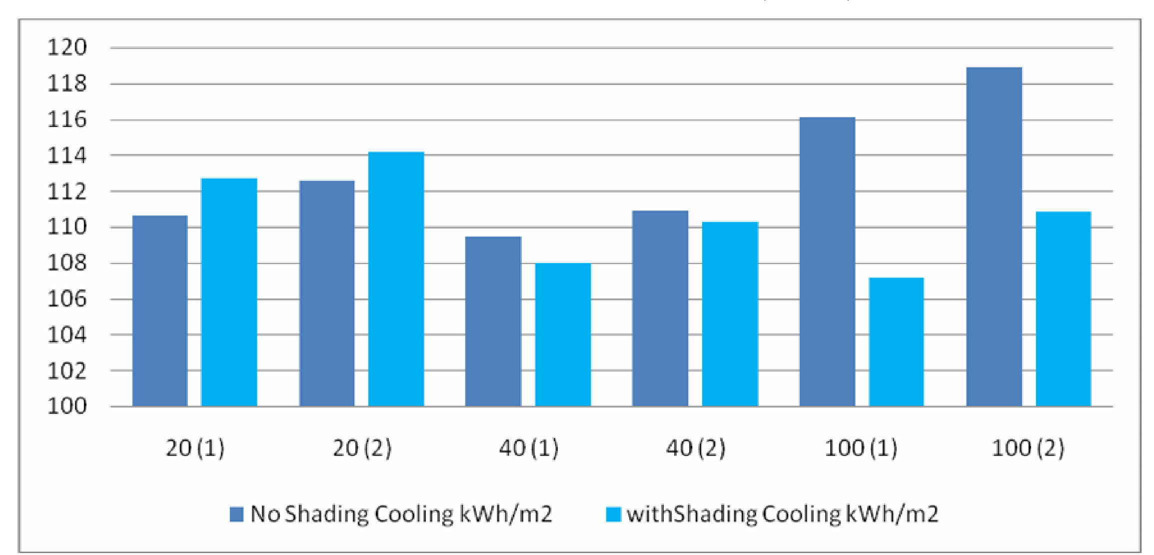
* (1) indicates no insulation with 1.8 $kW/m^2.k$ U-values.

(2) indicates Energy Efficient Building Code insulation requirement with 0.57 $kW/m^2.k$ U-values.

(3) indicates Green building guideline of Jordan insulation requirement with 0.45 $kW/m^2.k$ U-values.



Graph 44: Heating consumption for building Four, Single and Double Clear Glazing, for shaded and un-shaded cases, with no insulation*. (Author)



Graph 45: Cooling consumption for building Four, Single and Double Clear Glazing, for shaded and un-shaded cases, with no insulation*. (Author)

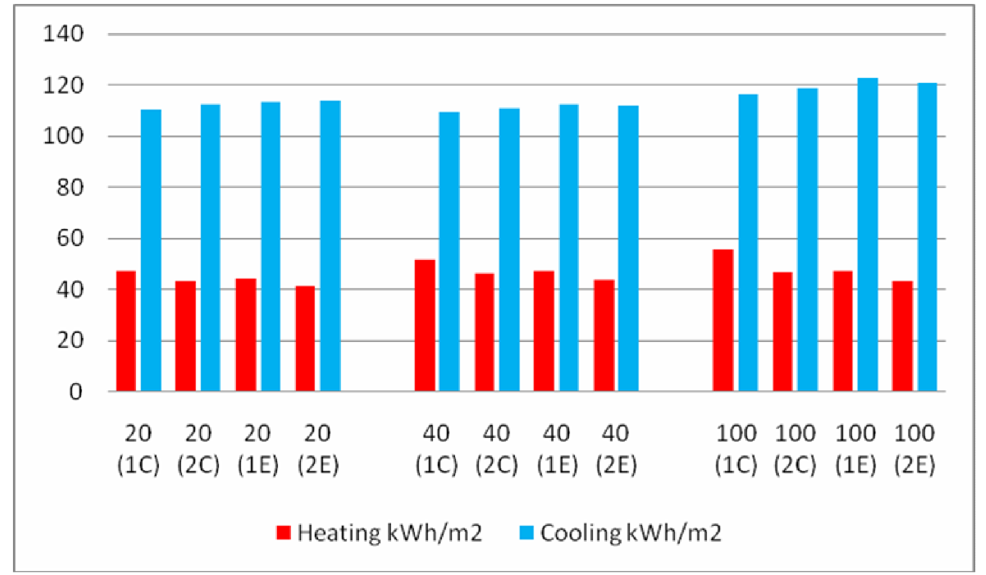
* (1) indicates Clear Single glazing.
(2) Indicates Clear Double glazing

Graph 46 indicates the effect of using Low-e glazing compared with clear glazing, for both single and double glazing, on heating and cooling demands for building Four, North-East Oreintation, with no insulation and no shading.

It was found that using double clear glazing gives almost the same effect of Single low-e glazing in energy consumption used for space heating.

However, in energy consumption used for space cooling, the type of glazing almost have no effect of savings for low WWR facades. On the other hand, for facades with high WWR, it is recommended **NOT** to use single low-e glazing, and recommended to use double Low-e glazing instead.

Graph 47 shows heating, cooling and total energy consumption when using adjustable shading devices in facades with double low-e glazing, where shading devices are only ON when they are needed, i.e. in the summer season. Graph 48 shows the same paremeters but with no shading

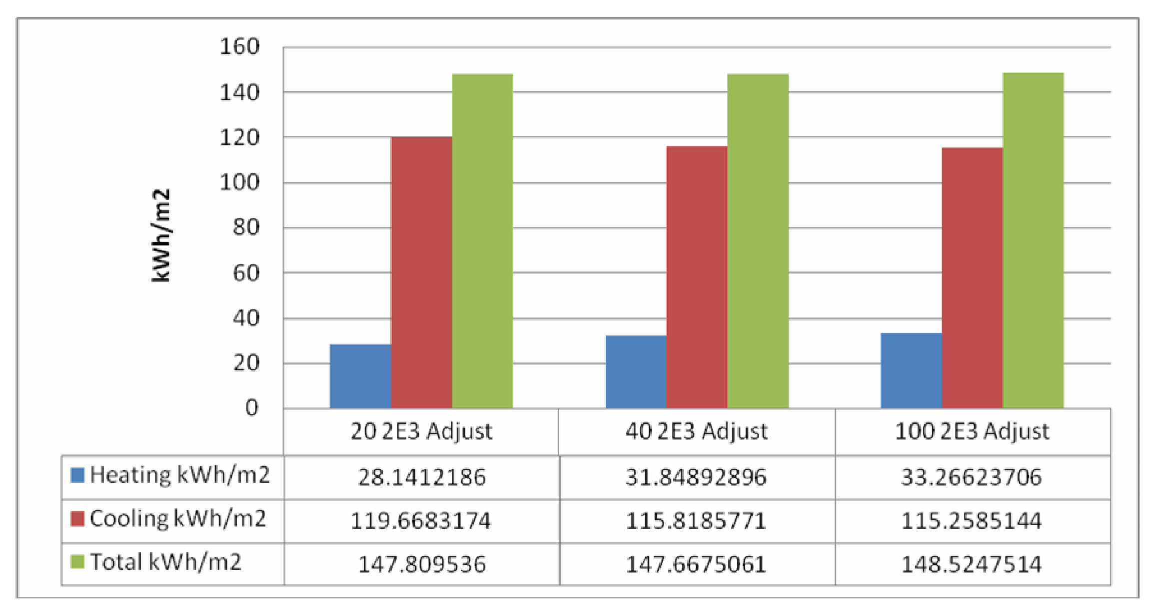


Graph 46: Heating and cooling demand for Building Four, using different types of glazing.* (Author)

* (1C) indicates Single Clear Glazing
(2C) indicates Double Clear Glazing
(1E) indicates Single Low-e Glazing
(2E) indicates Double Low-e Glazing

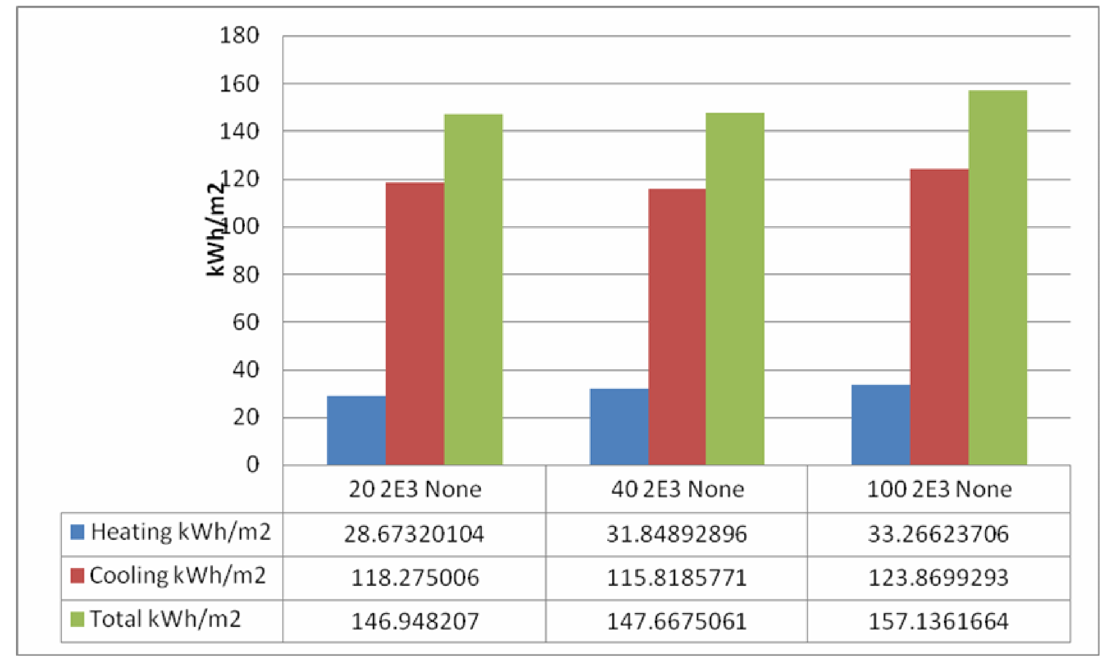
When comparing graph 47 with graph 48 for building Four, the North-East facing building, it was found that energy needed for space heating is still the same for both cases, indicating the use of un-shaded façade in winter. Moreover, when using adjustable shading in the summer. Graph 47 shows that cooling demand has been lowered by **2 percent** in comparison with the un-shaded case, leading to a lower value of total energy consumption reaching saving of **1 percent**.

However, the use of adjustable shading is more expensive than using fixed external shading. This concludes, that based on the very low saving parcentage adjustable and fixed shading devices offer, it is **NOT** recommended to invest in North-East facing buildings, regardless of façade WWR.



	20 2E3 Adjust	40 2E3 Adjust	100 2E3 Adjust
Heating kWh/m2	28.1412186	31.84892896	33.26623706
Cooling kWh/m2	119.6683174	115.8185771	115.2585144
Total kWh/m2	147.809536	147.6675061	148.5247514

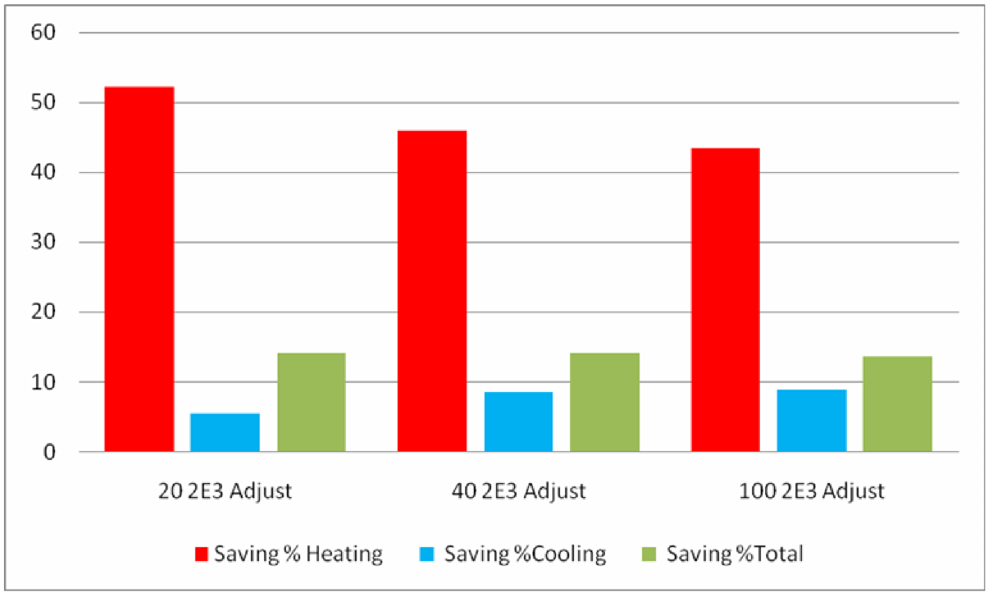
Graph 47: Heating, cooling and total energy consumption for building Four, Double Low-e glazing, with adjustable shading. (Author)



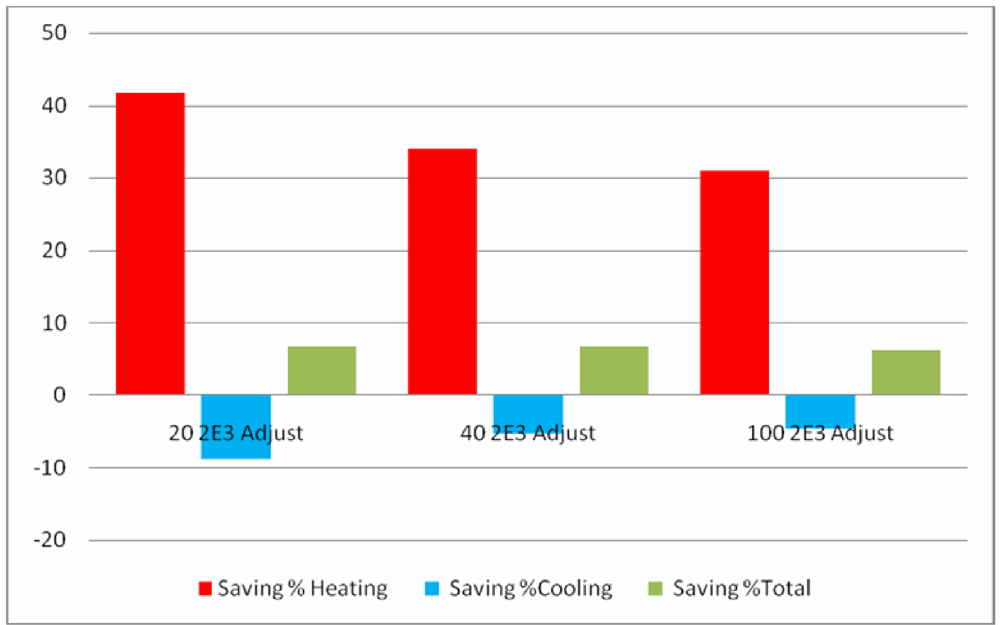
	20 2E3 None	40 2E3 None	100 2E3 None
Heating kWh/m2	28.67320104	31.84892896	33.26623706
Cooling kWh/m2	118.275006	115.8185771	123.8699293
Total kWh/m2	146.948207	147.6675061	157.1361664

Graph 48: Heating, cooling and total energy consumption for building Four, Double Low-e glazing, with NO shading. (Author)

Graph 49 illustrates savings (in percentage) in heating, cooling and total energy consumption for Building Four when using adjustable shading devices and double Low-e glazing for un-inulated building envelope, compared with worst cases results. See table (63) However, graph 50 shows savings for the same parameters but in comparison with the results of the Base case.



Graph 49: Savings (in percentage) in heating, cooling and total energy consumption when using adjustable shading devices in comparison with worst case senario, for Building Four, NE. (Author)



Graph 50: Savings (in percentage) in heating, cooling and total energy consumption when using adjustable shading devices in comparison with base case senario, for Building Four, NE. (Author)

Table (63) summeries the energy consumption results of the simulation of Building Four, the North-East Orientation, and savings compared with worst case senarios and savings compared with base case design senario for the following:

1) **Base case**
2) **Optimum cases (with adjustable shading devices)**
3) **Best cases**
4) **Worst cases**

Table (64) signifies the descending order of design senarios for Building Four, the North-East Orientation, from the best case recommended for North-East Facing buildings, to the worst case design senario, which should be forbiddened in North-East facing Buildings.

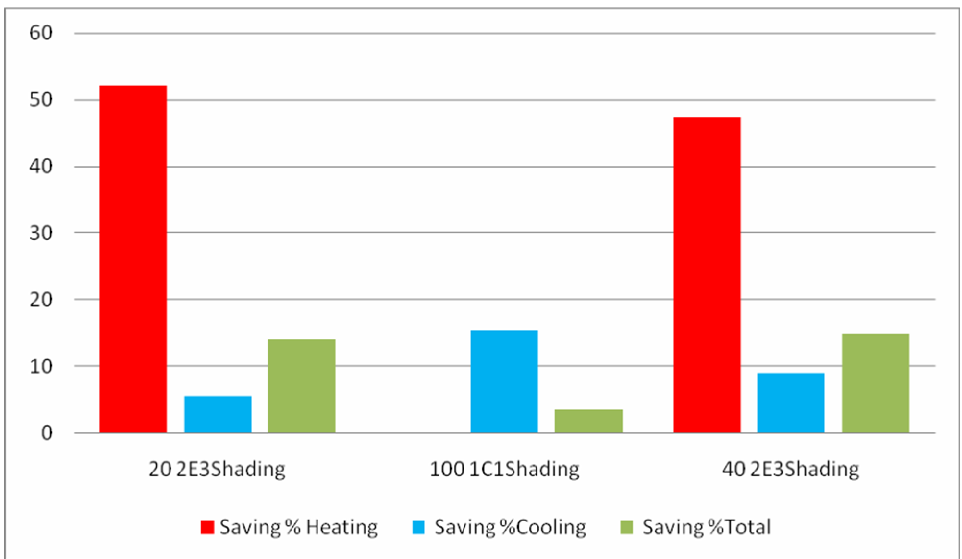
Graph 51 illustrates savings (in percentage) in heating, cooling and total energy consumption for Building Four when using best case senarios, compared with results of worst cases of the research. See table (63). However, graph 52 shows savings for the same parameters but in comparison with the results of the Base case design senario.

Table 63: Summery of results for Building Four, North-East Orientation (Author)

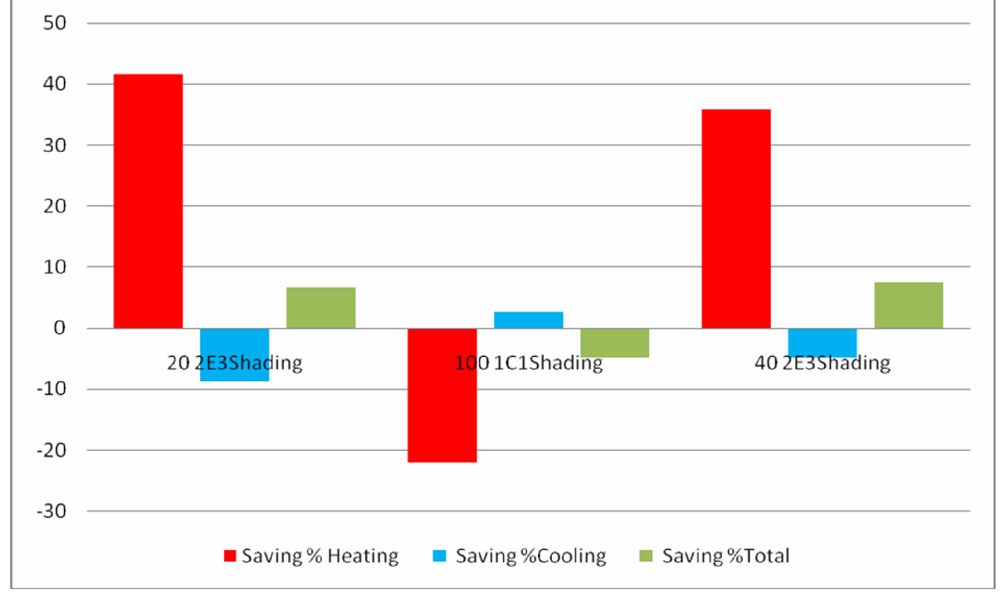
	Heating kWh/m^2	Cooling kWh/m^2	Total kWh/m^2	Compared with worst			Compared with Base		
				Saving% heating	Saving% cooling	Saving % total	Saving% heating	Saving% cooling	Saving % total
Base	48.22	110.04	158.27	18.00	13.01	7.89	0	0	0
Optimum									
20 2E3 Adjust	28.14	119.66	147.80	52.15	5.40	13.98	41.65	-8.74	6.61
40 2E3 Adjust	31.84	115.81	147.66	45.85	8.45	14.06	33.96	-5.24	6.70
100 2E3 Adjust	33.26	115.25	148.52	43.44	8.89	13.57	31.02	-4.73	6.16
Best									
20 2E3Shading	28.14	119.66	147.80	52.15	5.40	13.98	41.65	-8.74	6.61
100 1C1 Shading	58.82	107.15	165.98	0	15.29	3.41	-21.96	2.62	-4.86
40 2E3 Shading	30.97	115.31	146.29	47.33	8.84	14.86	35.76	-4.78	7.57
Worst									
100 1C1 Shading	58.82	107.15	165.98	0	15.29	3.41	-21.96	2.62	-4.86
100 1E3 None	37.32	126.50	163.83	36.55	0	4.66	22.61	-14.96	-3.51
100 1C1None	55.71	116.12	171.84	5.28	8.20	0	-15.52	-5.52	-8.57

Table 64: Descending Order of Design case scenarios for Building Three, North-West Orientation, from Best to worst **(Author)**

	Heating kWh/m²	**Cooling kWh/m²**	**Total kWh/m²**
40 2E3 Shading	30.97	115.31	146.29
40 2E3 Adjust	31.84	115.81	147.66
20 2E3 Adjust	28.14	119.66	147.80
100 2E3 Adjust	33.26	115.25	148.52
100 1E3 None	37.32	126.50	163.83
100 1C1 Shading	58.82	107.15	165.98
100 1C1 None	55.71	116.12	171.84



Graph 51: Savings (in percentage) in heating, cooling and total energy consumption when using best case design senario in comparison with worst case senario, Building Four, NE. (Author)



Graph 52: Savings (in percentage) in heating, cooling and total energy consumption when using best case design senario in comparison with base case senario, Building Four, NE. (Author)

4-6 Summary of Results Analysis:

The following points are concluded from table (65) below:

1) Double glazing always have positive effect on heating demand regardless of the orientation of the main long façade.
2) North-West and North-East Orientations of main facades do not require any shading devices at all.
3) Shading Devices are most important on high WWR facades facing South East.
4) Complying with the requirements of the EEBC is important for all buildings regardless of orientation
5) 100 percent of WWR with clear single glazing should be banned for North-East and North-West facing infill-buildings.
6) The optimum WWR for all infill buildings, regardless of orientation, is the 40 percent.

Table 65: Summary of results. (Author)

	Building 1 SW	**Building 2 SE**	**Building 3 NW**	**Building 4 NE**
	South-West	**South-East**	**North-West**	**North-East**
Optimum case name	40 2E3 Adjust	20 2E3 Adjust	40 2E3 Adjust	40 2E3 Adjust
Best case name	40 1C1 Shade	20 2E3 Shade	20 2E3 Shade	40 2E3 Shade
Worst case name	100 1E1 None	100 1E1 None	100 1C1 None	100 1C1 None
Cooling demand (%) from total	80	88	75	75
Heating demand (%) from total	20	12	25	25
Shading effect on heating (%)				
High WWR	Increase 27	Increase 45	Increase 14	Increase 4
Low WWR	Increase 19	Increase 40	Increase 3	Increase 3
Shading effect on cooling (%)				
High WWR	Decrease 24	Decrease 41	Decrease 18	Decrease 7
Low WWR	No effect	Decrease 30	Decrease 5	Increase 2
EEBC* effect on heating (%)				
High WWR	Decrease 25	Decrease 23	Decrease 15	Decrease 16
Low WWR	Decrease 40	Decrease 25	Decrease 19	Decrease 25
EEBC* effect on cooling (%)	Increase 7	Increase 4	Increase 3	Increase 3
Double Glazing effect on heating (%)	Decrease 15	Decrease 15	Decrease 15	Decrease 15
Adjust. Shading effect on cooling (%)	Decrease 20	Decrease 35	Decrease 16	Decrease 2
Adjust. Shading effect on total (%)	Decrease 17	Decrease 32	Decrease 13	Decrease 1

* *EEBC: Energy Efficient Building Code.*

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis and findings of the research, the following conclusions and recommendations can be drawn:

(1) It is concluded that the highest possible energy usage per meter square of area, for both heating and cooling demand, in infill-commercial-buildings in Amman is **258 kWh/m^2** consumed by infill-buildings facing the South-West orientation, when using single low-e glazing with 100 percent WWR, with no shading devices and no insulation in the building envelop, which is one of the worst case scenarios. On the other hand, the lowest possible energy usage per meter square of area, for both heating and cooling demand, in infill-commercial-buildings in Amman is **146 kWh/m^2** consumed by infill-buildings facing the North-East orientation, when using Double low-e glazing with 40 percent WWR, regardless of the availability of shading devices, and with Energy Efficient Building Code minimum insulation requirement in the building envelop. Consequently, the average energy use in infill-buildings in Amman is **200 kWh/m^2.** When supported with actual measurements, or field survey of electric bills and diesel costs annually, and comparing results of annual usage of energy concluded from this research, one can produce a benchmark data base for office buildings energy usage. This would be very useful for future studies on energy consumption in buildings.

(2) It is concluded that shading devices on the South-West and South-East orientations can make some relatively negative impact on heating demand needed in the winter season, due to lack of information on exact shading device requirements and dimensions, and the windows orientation. The solution is to use manual or

automatic movable external devices, that are operated to switch off in the winter season, allowing the total exposure to the solar heat, and the total protection from solar radiation whenever it is wanted. However, these types of shading devices are relatively costly, and feasibility studies should be done in order to choose this solution. Other forms of shading can be used, such as shaping the building form itself to be self-shading through wings and other mass articulations, balconies, deep reveals, or arcades. This can assist cooling energy demands and improving thermal comfort. Also, designing a facade with some depth creates a buffer zone that can contain shading elements and other modifiers to filter glare and blocks sun.

(3) It is recommended to emphasize on sustainability in terms of energy use and saving potential in awareness campaigns, workshops and training programs through this research's findings.

(4) It is recommended to incorporate thermal simulation program-teaching with other engineer's-related software's and computer programs and building envelope thermal assessment criteria in undergraduate curriculum; due to the inevitable and important impact it has on design and proper development of buildings, in order to broaden students and future engineers' perspective in design and construction.

(5) It is recommended to encourage the use of shading devices for both South-East and South-West facing buildings, by developing an incentive scheme for whom are responsible for the decision of using these criteria's, such as the owner, the designer, the constructor, or the client.

(6) It is recommended to encourage the use of double glazing in all of the main facades of infill-buildings regardless of the orientation, by developing an incentive scheme for whom are responsible for the decision of using these criteria's, such as the owner, the designer, the constructor, or the client.

(7) It is recommended that governmental bodies and the Greater Amman Municipality forbid, based on this research, the use of single Low-e glazing for South-West and South-East facing buildings, and forbid the use of single clear glazing for North-West and North-East facing buildings, when the window to wall ratio of the main façade is 100 percent, due to their high energy consumption levels compared with other materials and design scenarios.

(8) It is recommended for governmental bodies to develop incentive schemes for the use of automatically adjustable shading devices used on the main facades of commercial infill buildings, which can be adjusted to let in solar heat when ever needed, (winter season), and diffuse, reflect or block solar radiation in the summer season. These incentives are recommended in order to offset the high cost of adjustable shading devices, and to encourage the proper usage of these shading devices.

(9) It is recommended to insure the application of the minimum requirements mentioned in the Jordanian Codes of practice in general, and the mandatory requirements of the Energy Efficient Building code of Jordan, in regards to the architectural principles for designing a passive building as much as possible, merged with the urban content of the city and the developing technological applications in the construction industry.

(10) It is recommended that the methodology of this research can be evaluated in other climate zones in Jordan, such as in the city of Aqaba. Results of the same research in Aqaba are highly expected to differ and present different conclusions and recommendations.

(11) It is recommended that further studies should be done to evaluate benchmarks for base (or average) use of energy per meter square of area for different and all building functions, such as schools, office buildings, single residential dwellings, multi-residential complexes, etc. This is to create a local data base in which one can use to compare different strategies with basic energy consumption and properly choose optimum solutions.

(12) It is recommended that further thermal simulations should be done on basic orientations of main facades for the same four buildings addressed in this research, in order to compare results with the skewed orientations. Hence, the South-East facing building, for example, can be simulated to South for the same parameters for one study and to the East for the other. Another 288 plus 288 cases can be done on each building for the purpose of examining energy consumption differences in comparison with the basic building examined in the research.

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APPENDICES

APPENDIX A

BIO-CLIMATIC INDICATORS

A-1 Mahoney Tables:

The **Mahoney tables** are a set of reference tables used in architecture used as a guide to climate-appropriate design. They are named after architect Carl Mahoney, who worked on them together with John Martin Evans, and Otto Königsberger. They were first published in 1971 by the United Nations Department of Economic and Social Affairs. The concept developed 1968 by Mahoney in Nigeria. The Mahoney Tables proposed a climate analysis sequence that starts with the basic and widely available monthly climatic data of temperature, humidity and rainfall, or data published by national meteorological services. (Koenigsberger, 1969)

The tables use readily-available climate data and simple calculations to give design guidelines, in a manner similar to a spreadsheet, as opposed to detailed thermal analysis or simulation. There are six tables; four are used for entering climatic data, for comparison with the requirements for thermal comfort; and two for reading off appropriate design criteria (Heerwagen, 2003). A rough outline of the table usage is:

1. **Air Temperatures**. The max, min, and mean temperatures for each month are entered into this table.
2. **Humidity, Precipitation, and Wind**. The max, min, and mean figures for each month are entered into this table, and the conditions for each month classified into a *humidity group*.
3. **Comparison of Comfort Conditions and Climate**. The desired max/min temperatures are entered, and compared to the climatic values from table 1. A

note is made if the conditions create *heat stress* or *cold stress* (i.e. the building will be too hot or cold).

4. **Indicators** (of humid or arid conditions). Rules are provided for combining the stress (table 3) and humidity groups (table 2) to check a box classifying the humidity and aridity for each month. For each of six possible indicators, the number of months where that indicator was checked are added up, giving a yearly total.
5. **Schematic Design Recommendations**. The yearly totals in table 4 correspond to rows in this table, listing schematic design recommendations, e.g. 'buildings oriented on east-west axis to reduce sun exposure', 'medium sized openings, 20%-40% of wall area'.
6. **Design Development Recommendations**. Again the yearly totals from table 4 are used to read off recommendations, e.g. 'roofs should be high-mass and well insulated'.

A-2 Givoni Graphs:

In 1969, Baruch **Givoni** developed the building bioclimatic charts for “envelope-dominated buildings” with no mechanical system. His charts were based on indoor temperature. He used his Index of Thermal Stress (I.T.S.) index to identify the limits of external climate conditions for each effective design strategy boundary that would be used to attain indoor comfort conditions. Givoni’s bioclimatic charts have been widely referenced by many studies. (Lam Ngan Tung, 2008)

In 1979, Milne and Givoni combined the different design strategies into the same chart. They determined the limits of effectiveness for each design strategy in order to meet the needs of indoor comfort. Their chart is based upon the previous

study conducted by Givoni (1976). The G-M Chart determines for each design strategy the limits of their effectiveness to meet the needs of indoor comfort conditions. It should be noted that Milne and Givoni considered the boundaries to be fuzzy, and even ambiguous. This is indicated by the arrows that they frequently include on their chart.

In one of the ways to use their chart, hourly weather data for a location can be superimposed onto the chart to calculate the number of hours that fall into each design strategy in order to find the appropriate design strategies for that location.

APPENDIX B

JORDANIAN CODES OF PRACTICE

B-1 Introduction:

The basis and principles of Jordan National Building Codes are formulated under Law No.7 (1993)- Jordan National Building Law, and the Amended Law for year 2004. Building Codes of Practice and specifications are normally prepared and updated by researchers from the Building Research Center (BRC) of the Royal Scientific Society (RSS). Furthermore, preparation & updating can be with the collaboration of researchers from both the private and governmental sectors. Afterthat, the codes are approved by the Jordan National Building Council.

These codes were first enacted by the Jordan Government in 1985. they are prepared to serve all the different disciplines of engineering and scientific sectors, keeping up with new developments and legislations.

Currently the procedure for a new code or the amendment of an existing one follows the steps below;

- The Ministry of Public Works and Housing (MPWH) or RSS approaches the Jordan Natioanl Building Council (JNBC) to develop or amend a code.
- The JNBC mandates the development of the code to the RSS.
- The RSS prepares the first draft.
- JNBC forms a committee of experts from Public, Private sectors and Academia to review the code.
- A second draft is prepared according to the committee's deliberations, discussions and notes.
- The second draft is discussed, amended and approved by the JNBC Technical Committee.

- The technical committee raises the third draft for the Council and the draft is re amended according to notes and comments by the member organizations and thereafter approved.
- The approved draft is offered for the general public for objections for the period of 60 days and the comments and objections are presented to the Technical Committee within 15 days for its consideration with a maximum period of 3 months, thereafter the JNBC will raise the code to the Jordanian Council of Ministers for approval.
- The council of ministers approves the final draft and its use becomes Mandatory.

Table (B-1) shows the 38 codes of practice that Jordan apply:

B-2 Energy Related Codes of Practice:

The Royal Commission on energy initiated the development of the following codes at the end of 2007;

- Updating the existing Thermal Insulation code.
- Drafting a new Energy Efficient Buildings code.
- Drafting a new Gas Piping in Buildings.
- Drafting a new Solar Energy Code.
- Drafting a new Green Building Guideline for Jordan.

Table 66: Jordan codes of practice

Code	Code Name	Publication Year
1	Generalities	1993
2	Loads and Forces	2006
3	Site Investigation	1990
4	Bases, Foundations and Retaining Walls	2007
5	Structural Concrete	2008
6	Pre-stressed Concrete	1994
7	Steel Structures	2002
8	Formwork	1993
9	Scaffolding	1988
10	Masonry and Walls	1990
11	Building Materials and Their Usages	1988
12	Space Requirements in Buildings	1993
13	Thermal Insulation	2009
14	Acoustics For the Buildings	1988
15	Fire Protection	2004
16	Natural Ventilation and Sanitary Requirements	1992
17	Natural Lighting	1992
18	Water Supply for the Buildings	2003
19	Plumbing	1988
20	Urban Aesthetics	2008
21	Refuse Disposal	1988
22	Public Safety At Construction Site	1988
23	Electrical Installations	2008
24	Internal Lighting	1988
25	Earthing	1988
26	Lightning Protection	1988
27	Fire Alarm Systems	2004
28	Lifts	2008
29	Central Heating	1990
30	Mechanical Ventilation and Air Conditioning	1988
31	Shelters	1993
32	Building Requirements For the Disabled	1993
33	Water and Dampness Insulation in Buildings	2002
34	Fire Fighting Systems	2004
35	Earthquake Resisting Structures	2006
36	Energy Efficient Buildings	2010
37	Gas network for buildings	2010
38	Green Building guideline	In progress

B-3 Thermal Insulation Code:

Objective: This code aims at defining the building thermal design principles, and the methods for calculating the thermal characteristics of different structural elements. Additionally, furnish the minimum thermal requirements for these elements to facilitate the best selection by the engineers to achieve thermal comfort in buildings. This code was issued in 1985 and updated in 2008.

Scope: This code is updated to reduce the consumption of the fuel through the application of specific requirements and provisions.

Contents: Chapter One: Symbols of terms used in this code in addition to some important definitions.

Chapter Two: Materials used in thermal insulation and characteristics

Chapter Three: Principles of thermal design

Chapters Four: Thermal design calculations

Chapters Five: Design requirements

B-4 Energy Efficient Building code:

B-4-1 Justifications:

- No oil resources.
- Growing building sector, no environmental consideration.
- Pollution, energy consumption is high.
- Exceptional environmental circumstances.
- Lack of data, references, materials and techniques.

B-4-2 Objectives:

Applying the findings of this project will ensure:

- Better practice in the building sector in terms of environmental needs.
- Lowering heating and cooling bills.
- Improving the thermal conditions inside buildings
- Minimizing the negative effect of energy consumed in heating & cooling.

B-4-3 Contents- Chapter One: Generalities

- Objectives of the code: providing the architect and designer with the minimum requirements for designing an energy efficient building.
- Domain of Practice: all new construction, and any new extensions that consume energy, mandatory for building envelop, mechanical systems, electrical lighting, electrical power equipments and water heating system.
- Application method.
- Technical requirements for admission of Designs.
- Inspection and investigations.
- Architectural definitions.
- Mechanical Definitions.
- Electrical definitions.

B-4-4 Contents- Chapter Two: Architectural design principles and requirements:

- General; thermal design and passive design and climate design importance on the architectural elements of a building
- Objectives of Architectural design: thermal comfort, minimizing energy consumption, lowering energy bills.

- Architectural design considerations: climatic data of site, internal circumstances, building and space function, building material properties, tools and methods for application.
- Architectural requirements:
    a. Climate zone and region: tables for temperatures, humidity, wind speed, radiation and any other climate data important for the design.
    b. Site and orientation: utilization of the site advantages and finding ways to minimize effect of disadvantages concerning wind direction and speed, desired solar radiation and temperature. Recommendations were given, no obligatory: preferred building to the south, long axis directed east west, in hot areas using arcades and shading in the south façade, balconies and terraces to the south and east.
    c. Building form: relationship between exposed surface and volume with energy loss and gains, effect of height of building and shape of plan (high-rise building plans, shallow plan and deep plans), shape of building roof, shape of building walls, recommendations only.
    d. Site landscaping: recommendations only: deciduous trees for south facades, height of trees relationship with tree location, shadow consideration in cold areas, evergreen trees for hot climate, green landscaping (solar reflection), wind breakers from trees.
    e. Passive solar techniques for thermal efficiency: direct solar gain and loss through windows, thermal storage wall, sunspace.

f. Building Envelope: Thermal insulation and u-values, obligatory requirements for U-values (see tables), recommendation: solar reflectance higher than 0.7 for roof (light colors), smooth surfaces, Emissivity higher than 0.75 and absorption higher than 0.3 for roof, window areas concerning function and location and orientation, minimum areas in wind exposed windows, locations of functions on the plan related to orientation, service areas locations.

g. Sealing of opening: air leakage, requirements: air leakage not more than 3 liters/second for doors, and 2 l/s for other vertical openings, windows and doors sealing, insulation materials connections (thermal bridges), piping and services holes, shutter boxes.

h. Natural lighting:

   - Importance of natural lighting in minimizing electrical energy consumption.
   - Skylight and window lighting and their properties.
   - Requirements: obstacle angle in front of window not more than 70 degrees, 50% of opening should be on at least 2 different sides, ratio of window to wall area above10% for services, 15% for residential functions, visual lighting transmittance above 0.45, skylight maximum area 12% from roof, light colored internal surfaces.
   - Recommendation: organized distribution of windows, window height, window location.

i. Shading devices: objectives, types and uses (horizontal, vertical, crossed, movable, natural, internal), dimensions, requirements (void between external

shading device and window, light materials) recommendations (shading coefficient less than 0.2, movable shading on east, south east, west, west south facades, external better than internal)

j. Natural ventilation: ventilation advantages, minimum ventilation rates, requirements (first phases of design, distance not more than 5 times the height between too walls or out side and inside, humidity 40% to 70%, shaded ventilation point, avoid pollution points near ventilation points) recommendations: architectural solutions for protection from dust and for maximizing benefit from natural ventilation, small openings in big ones, additional ventilation equipments for redirecting air, uses of colestra brick and meshes in front of openings), means of natural ventilation: (one side, two side, cross ventilation, stack effect) elements of ventilation (opening width, inlet and outlet dimensions, partitions), means of improving natural ventilation (night ventilation, shaft, chimney, wind catcher), courtyard and atrium (usage, requirements: beginning of design, openings on court, ventilation points to get rid of hot air, proper shading devices).

Table 67: Walls U-values, Energy Efficient Building Code of Jordan (EEBC, 2010)

Walls	**U-value W/m^2.K**
Opaque walls or any part of it	0.57
Total Wall including percentage of openings	1.6
Divider walls between 2 different energy source provider for 2 building spaces.	2.0
Divider walls between 2 parts of the building one of them is heated/ air-conditioned and the other not.	2.0

Table 68: Exposed Floors and roofs U-values, Energy Efficient Building Code of Jordan (EEBC, 2010)

Exposed Floors and roofs		U-value W/m^2.K
Exposed for outdoor air	Heat transfer towards the top	*(1.2) 0.55
	Heat transfer towards the bottom	0.8
Floors/ Roofs dividing to floors with different energy source provider		1.2
Floors located above un heated/ air conditioned basements or spaces		1.2

Table 69: Windows U-values and window to wall allowed ratio. (EEBC, 2010)

Window type	U-Value (window) W/m^2. K	Allowed window to wall ratio
Windows with aluminium/ steel frame, single glazing	5.7	20.1%
Windows with aluminium/ steel frame, Double glazing	3.4	32.9 %
Windows with wooden/ plastic frame, single glazing	4.8	24.3 %
Windows with wooden/ plastic frame, double glazing	3.1	40.7 %

B-4-5 Contents- Chapter three: Mechanical ventilation

Field of application, Types, mandatory requirements

B-4-6 Contents- Chapter four: Heating and air conditioning

Design considerations, general requirements (device accreditation, duct system, electrical wiring), mandatory requirements for non residential buildings, Energy Efficiency Labeling, control devices, piping and ducting systems, system balance, thermal condensers, economizers, air conditioning systems

B-4-7 Contents- Chapter five: Hot water supply

Device placing, hot water demand calculation, piping insulation, equipment efficiency, control system, swimming pools.

B-4-8 Contents- Chapter Six: Lighting system

General, Lighting controls, power consumption in lighting, power consumption in outdoor lighting, recommendations.

B-4-9 Contents- Chapter Seven: Electrical power

Requirements (transformers, motor efficiency, inspection and monitoring, distributor efficiency) recommendations.

B-4-10 Appendices:

a. Jordan climate data

b. U-values for openings

c. Physical properties of building materials

d. Internal shading devices

e. Shading devices and sun charts

f. Ventilation

B-5 Solar Energy Code:

Objective: This code seeks to define the minimum requirements and standards that must be followed in solar thermal systems, and the solar photovoltaic systems. The provisions of this code shall be applied to the erection, installation, alteration, addition, repair, relocation, and replacement, in addition to the use and the maintenance of solar systems. Furthermore, it encourages the public and investors for the use of solar energy in residential and industrial purposes as an alternative source of energy to reduce fuel consumption.

Scope: This code encourages the public and investors for the use of solar energy in residential and industrial purposes as an alternative source of energy to reduce fuel consumption.

Contents: **Part one:** Solar thermal systems**:** Piping, Joints and Connections**,** Thermal Storage, Collectors**,** Thermal Insulation**,** and Duct Works

Part Two: Solar Photovoltaic Systems.

B-6 Green Building Guideline for Jordan:

Green design practices include a holistic approach to understanding a building’s total impact on the environment. The green building guideline and rating system for Jordan is Referenced to Jordan's Related Building Codes (as compulsory requirements), and International green rating systems such as LEED from the United states, BREEAM from the united kingdom, ESTIDAMA from Abu Dhabi , Dubai green building rating system, QSAS from Qatar, and many more.

The Royal Scientific Society of Jordan finished the preparation of the Green building guideline with parameters and credits that are suitable for Jordan’s climate, resources, legislation, policies and policies instrument, building techniques and strategies. This Guideline is attached to a Voluntary rating system that is connected to an incentive scheme given by the government.

Since green buildings have a profound impact on our natural environment, economy, health and productivity, the guideline assess building designs in **six** key areas: Green Building Management, Site Sustainability, Water Efficiency, Energy Efficiency, Healthy Indoor Environment and, Materials and Resources.

Within the scoring system, the energy efficiency part has possessed 33 percent of the total points given to a green building; this is due to the importance of energy in Jordan. The following table shows the pointing system and weights given:

Table 70: pointing system and weights. (GBG, 2010)

Chapters	points	weight
Green Building Management	20	6%
Site Sustainability	24	8%
Water Efficiency	110	35%
Energy Efficiency	98	33%
Healthy Indoor Environment	24	8%
Materials and Resources	32	10%

APPENDIX C

ADDITIONAL CASE STUDIES

C-1 Case Study No. 1:

Subject: Modeled Case Study of PDEC in Office Building in Amman, Jordan

Author: Rula Sa'ad Al Asir

Date: 2006

Source: Global Conference of Renewable Energy Approaches for DEsert Regions [GCREEDER] 18-22 September 2006.

Abstract: The aim of this paper is to develop a numerical method to define the architectural parameters of wind tower that may help to achieve thermal comfort for occupants in an office building.

The reliability of the assumptions is analyzed by computer simulation (TAS) to investigate the possibilities of applying a traditional style PDEC tower to office building Amman, Jordan.

The outcome is promising as the simulation results, temperature and humidity, were within ±1°C and ±5% from the target values. 6m high evaporative column model managed to drop the external temperature from 31.8°C to 27.7°C in the 2256m^2 - office modeled case study using 64.6 liter of water per hour.

A small amount of dehumidification is needed, over the cooling season, to bring the internal conditions into the comfort zone; 80.7 kWh or 0.0037 kWh/m^2 treated area.

Comments: Using numerical methods and simulation programs to define architectural parameters in thermal simulations is what this thesis seek. However, the use of the TAS program is currently not a choice available on the table. This is due to the high cost of attaining usage permission of the program, nevertheless, the high demanding training program required in order to use TAS. The author herself took her master's degree in training and using the program for the purpose of her study.

C-2 Case Study No. 2:

Subject: An approach to use building performance simulation, to support design optimization.

Author: Christina Hopfe and Jan Hensen

Date: 2005

Source: Building Performance Simulation (BPS) Unit Journal, Technische Universiteit Eindhoven, Netherlands, 2005.

Abstract: This study involved using building performance simulation to support design optimization during the later phases of the design process, where currently building simulation is merely used for code compliance checking; it is determined to the duration of 4 years.

The work consists of a study of design optimization tasks in the field of building simulation resulting in the specification of requirements for building performance tools supporting design optimization. This specification will then be used to assess existing software on their applicability to support design optimization.

The literature review, interviews as well as the design team observation show that there is a big need of using building performance simulation for design optimization in the detailed design stage. The conducted interviews and the software review on the other hand reveal that there is big mismatch between the user expectations and the implementation of the desired functions in those tools.

Comments: The study supports the objective of the thesis; using simulation tools in the design process, even in the conceptual design assessment phase, will back up architectural and electro mechanical choices for energy efficiency.

C-3 Case Study No. 3:

Subject: Multi-functional transparent PV-façade for the energetic, Rehabilitation of an office building in Barcelona.

Author: Torsten Masseck

Date: 2002

Source: Polytechnic University of Catalonia (UPC) Publications, Catalonia, Spain

Abstract: The present paper shows an example for an integrated design process in the field of solar architecture, combining the design work of the architect, the use of simulation tools and the applied research on new combinations of materials like amorphous silicium, semi-transparent PV panels and colored glass, with the aim of the energetic optimization of an architectonical project.

The report shows the case study of an energetic rehabilitation of a five-story staircase and the adjacent zones that suffered severe problems of overheating and cold due to an insufficient ventilation, the lack of sun shading, and an overall deficient thermal behavior.

Industrial fixed glazing elements are substituted by a multifunctional double-glazed facade consistent of a combination of transparent PV panels and colored glass elements. An intelligent natural ventilation strategy is developed to cope with the special condition of the staircase as intermediate space between the air-conditioned office space and the exterior.

Thermal measurements were made before and after the intervention. Simulation tools were used to define the right combination of materials in terms of sun shading, daylight use, electricity production and architectonical quality.

A thermal simulation with TRNSYS was made to evaluate the effect of the proposed design on the thermal behavior of the building and to optimize the proposed strategies in the field of sun protection and natural ventilation.

Different sizes of openings were simulated to define the requirements for sufficient natural ventilation.

The chosen construction system, a semi-structural curtain wall façade, already conditioned the possibility of integration of openings. For design reasons there was a first decision for so called Italian windows, opening towards the outside, and in closed position almost invisibly integrated like fixed glazing elements.

This façade system showed to be a problem in terms of shadow projection on the PV panels in the upper part of the façade. Even a 15-degree opening would have caused shadow on some part of below installed ASITHRU photovoltaic elements, causing a notable loss of productivity of the whole PV installation.

So finally the decision was made to introduce a line of windows in the upper part of the façade, which open to the inside, permitting fully opened a free ventilation opening of 1,6 m^2, required minimum according to the TRNSYS simulation results.

According to simulation results, with the new facade the overall heating and cooling demand of the office building could be reduced by 8 percent, dropping from about 87 kWh/m^2 to approximately 80 kWh/m^2.

Comments: Combinations between architectural solutions and technological ones can be accomplished with the assessment of simulation tools such as TRNSYS. This study shows high potential in energy efficiency assessment for technological parameters. Although integral approach between all architectural and engineering specialties is most recommended for proper design of energy efficient buildings, the thesis concentrates on available architectural knowledge-base and technologies, in order to backup minimum requirements for an energy efficient building with restricted façade orientation.

C-4 Case Study No. 4:

Subject: Optimization of the energy performance of multiple-skin facades.

Author: Dirk Saelens, Bert Blocken, Staf Roels, and Hugo Hens,

Date: 2005

Source: Ninth International IBPSA Conference Procedings, Montréal, Canada, August 15-18, 2005, (Building simulation 2005).

Abstract: This paper describes how the energy performance of single storey multiple-skin facades can be optimized by changing the settings of the facades and HVAC system.

The energy performance is analyzed with a yearly whole building energy analysis under Belgian climatic conditions. Three multiple-skin facades are scrutinised: a mechanically ventilated airflow window, a naturally ventilated double-skin façade and a mechanically ventilated supply window. Their performance is compared against the performance of a traditional cladding with exterior and interior shading device. It is shown that both the heating and cooling demand may significantly be improved by implementing control strategies such as controlling the airflow rate and recovery of air returning from multiple-skin facades.

To analyze the energy demand, a modeling environment combining a model of the facades, a model of the office zones, a model of the heating and cooling system and a model of the building energy management system has been developed. All models are combined into TRNSYS energy simulation program.

The energy efficiency objectives obviously depend on the multiple-skin facades (MSF) typology. Unfortunately, most MSF-typologies are incapable of lowering the heating and cooling demand simultaneously. Only by combining typologies or by changing

system settings according to the particular situation, a substantial overall improvement over the traditional solutions is possible. This implies that control mechanisms are inevitable to make MSFs work efficiently throughout the entire year.

In this paper, different strategies to optimize the energy efficiency of multiple-skin facades were studied and compared against the results of traditional cladding systems.

By implementing control strategies the energy efficiency of all facade systems is significantly improved.

The supply window has the highest potential to benefit from the optimization techniques. It is able to considerably reduce the heating demand while providing an acceptable cooling demand. The traditional facade with exterior shading device, however, still provides the best solar protection. The double-skin facade is also able to efficiently control the cooling demand but is limited to improve the heating demand. The airflow window is capable of significantly lowering the heating demand but still suffers from high cooling demands.

Comments: This study shows that some technological strategies need automotive control systems attached in order to assure internal comfort for tenants in residential buildings. However, this thesis concentrates on finding proper combinations of passive solar design methods and controls in commercial buildings, including the use of double skin facades as one of the options for providing highly modernized glazed facades with high insulation properties. Nevertheless, from the view of the Jordanian market, developers tend to use every meter square of the building and land available in order to attain feasible rents and sales. Consequently, double skin facades consume meter squares; hence, this research would not cover this option in studied design criteria's.

C-5 Case Study No. 5:

Subject: iGuzzini Headquarters (the Italian light house), Office building, Italy.

Designer: Mario Cucinella Architects

Date: 2006

Source: Lerum, 2008, p. 186

Abstract: The idea is that the building is like a leaf. The building is facing south to get to the most energy possible but also optimizing daylight design for the minimising of energy and electricity usage.

Great detail was given in choosing materials. A lab experiment was to test the quality of the skylight—how different colors, reflectivity, and materials would influence the quality of light. The seasons of the year were analyzed: At 12 noon on June 21 there is no sun entering the space.

The large areas of glass on the north and south façades, along with a light shelf, were intended to allow for daylight to enter deep into the building.

On the south side, there is a shading device with horizontal louvers. The effect of these horizontal louvers on the daylight levels inside the offices was investigated in two ways: First, a three-dimensional model of the south half of the building was constructed using the Sketch Up Pro computer program. Then, upon arrived at the site, photos of the shade pattern on the ground—created by the shading structure—were analyzed. This was to study shading of the building and its effect on daylight availability.

Comments: The results of this study were dependant on 'visual' conclusions generated of the shape and area of shade. More can be done by a software that can give both, visual and thermal representations of the study.

C-6 Case Study No. 6:

Subject: Eco House

Author: Amer A. Maraqa, Moath Heeh, Hazem Mubarak, Motasem Darwesh

Date: 2010

Source: Global Green Techies Forum and Exhibition, (GTFEX), Sep. 2010.

Abstract: The Idea of this project was born corresponding to the Green Building Design Competition, which was held over the country level, for engineering faculties' students of Jordan Universities. The competition aimed to motivate the students to extract their latent potential to produce designs which are promising to face the challenges in the energy, economy, and environment sectors, which are related to the design of the residential buildings.

The building has been constructed over a land of 600 m^2, which is situated at Queen Alia Airport Street, taking into consideration the different design criteria. The different green and sustainable aspects have been studied for the building, where the building has been modeled using "DesignBuilder®" building energy simulation tool. Based on the simulation data which expect the annual energy consumption, by having plots of the design variables, the best building environment with a compromised envelop could be selected to satisfy its heat tightness and its economy and human well being.

Eco House design has won the first award in the competition. The students have worked on the project under self-Supervision.

Comments: DesignBuilder® is the software used in this study, were it is the same software that will be used in this thesis. The results of the previous competition entry and winner, shows that undergraduate students can achieve great

deal of decisions using the DesignBuilder® software, both for comparison between design parameters and the verification of their choices regarding energy efficiency.

Note: the Author has contributed in the judgment committee for the competition in which this project has won.

C-7 Case Study No. 7:

Subject: Deutsche Post headquarters, Office building, Germany

Designer: Helmut Jahn

Date: 2005

Source: Lerum, 2008, p. 145- 161

Abstract: In the subject building, half-shells separated by nine-story sky gardens, generate the form of a typical office floor plan. A two-story space and a penthouse with a screened roof terrace define the executive areas at the top of the building. Two groups of glass elevators, separated by glass floors, serve all floors. It is essentially two buildings that act together as one structure by means of large diagonal cross-bracing. The building envelope is dominated by a fully glazed double-skin façade that enables natural ventilation and protects the interior from noise, rain, and wind. Perforated Venetian blinds are placed between the two glass shells of the façade, for sun protection and glare control. Fresh air is preconditioned as it passes through the double-skin façade. The displacement ventilation principle is used for air distribution. Heating and cooling is primarily provided by a radiant system embedded in the coffered exposed concrete slabs.

The south side is shingled to take into account the solar loads and the north side is flat. On a hot summer day, air will move up inside the cavity of the double-skin façade. A vertical airflow on the outside of the blinds allows the heat to be vented

out at the top of each nine –story segment. The atria have large operable windows at both sides, and it's all motorized.

Comments: Double skin facades can contribute to high energy savings, only if they are collaborated with a highly sophisticated automated control system to avoid over heating or unwanted draft. Again, double-skin facades will not be investigated in this thesis because of its high cost and low-space feasibility.

C-8 Case Study No. 8:

Subject: Energy Efficient Building Design.

Author: Mohmuod A. Hassan and Ahmed A. Medhat A. Fahim.

Date: 2009

Source: Building Physics Dept. at Housing and Building National Research Center Publications, Cairo, Egypt, 2009.

Abstract: In this work an investigation is carried out of several ways in which the building energy consumption can be reduced, in order to verify the concept of green architecture. An investigation of reducing the cooling load in summer by using different insulation materials was carried out to determine their effects on the total annual energy. The computer packing "Visual DOE" that was developed as part of EEEGIR (Energy Efficiency Improvement and Green House Gas reduction Project code) for residential and commercial buildings in Egypt was used.

It is concluded that Perfect roof insulation is recommended for all conditioned rooms. The study also recommend that, whatever the insulating material type, the external location is more effective than the internal position.

Comments: Results of this study will be taken into consideration when applying the insulation parameter on the case study simulation; i.e. insulation will be located in the exterior layer of walls and roofs.

APPENDIX D

EXTENDED RESULTS

Table 71: Building One South-West- Extended Results (monthly Data)

Building One Base Case

Date/Time	System Misc	Heat Generation (Oil)	Chiller (Electricity)	DHW (Electricity)	Outside Temperature
	kWh/m2	kWh/m2	kWh/m2	kWh/m2	°C
1/1/2002	2.75474	17.44162	1.93E-02	1.999321	8.013307
2/1/2002	3.049891	13.03693	9.23E-02	1.778034	8.615029
3/1/2002	2.951507	12.09358	0.2671575	1.927493	9.745699
4/1/2002	3.049891	4.349129	3.268767	1.925558	13.88528
5/1/2002	2.951507	3.80E-02	14.03862	1.999321	19.40779
6/1/2002	3.049891	2.83E-03	18.54911	1.853731	20.98195
7/1/2002	3.049891	0	35.33598	1.999321	22.73441
8/1/2002	2.951507	0	35.26139	1.963407	23.04382
9/1/2002	3.049891	1.52E-04	29.23052	1.889645	21.49319
10/1/2002	2.951507	1.29E-02	21.6716	1.999321	19.88199
11/1/2002	3.049891	0.8023283	4.876445	1.889645	14.60778
12/1/2002	3.049891	13.8408	0.5169299	1.963407	9.495833
	35.910005	61.61825015	1.63E+02	23.188204	

Building One 20% WWR No Shading

Date	Outside Temperature	1C1 Heat Generation (Oil)	1C1 Chiller (Electricity)	1C1 Total (Energy)	1C2 Heat Generation (Oil)	1C2 Chiller (Electricity)	1C2 Total (Energy)	1C3 Heat Generation (Oil)	1C3 Chiller (Electricity)	1C3 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	19.43634	2.8039E-05	19.43637	11.6455	0.00075955	11.64626	11.94262	0.00090846	11.94353
2/1/2002	8.615029	14.91231	0.01163739	14.92395	8.861951	0.04956837	8.911519	9.11804	0.05276311	9.170803
3/1/2002	9.745699	13.7046	0.08302054	13.78762	8.4454	0.2397751	8.685175	8.777382	0.2433198	9.020702
4/1/2002	13.88528	4.980709	2.43585	7.416559	2.830828	3.26089	6.090718	3.026	3.277104	6.303104
5/1/2002	19.40779	0.05093957	12.73787	12.78881	0.02213024	13.7375	13.75963	0.02333991	13.71788	13.74122
6/1/2002	20.98195	0.003189362	17.53684	17.54003	0.001463455	18.3128	18.31427	0.001593358	18.2846	18.28619
7/1/2002	22.73441	0	33.98513	33.98513	0	33.63233	33.63233	0	33.70329	33.70329
8/1/2002	23.04382	0	33.21848	33.21848	0	32.87267	32.87267	0	32.99818	32.99818
9/1/2002	21.49319	0.000311079	26.29877	26.29908	3.93953E-05	26.85326	26.8533	7.05357E-05	27.0707	27.07077
10/1/2002	19.88199	0.01786317	18.43332	18.45118	0.004394084	20.05844	20.06308	0.005227736	20.37066	20.37589
11/1/2002	14.60778	1.033883	3.008814	4.042697	0.3020396	4.867956	5.169996	0.3163824	5.004509	5.320891
12/1/2002	9.495833	15.26162	0.187765	15.44939	8.943298	0.5934873	9.536785	9.254029	0.6022121	9.856241
		60.40176518	147.937525	217.3393	41.05674577	154.478936	195.5357	42.46468496	155.326126	197.7908

Building One 20% WWR No Shading

Date	Outside Temperature	1E1 Heat Generation (Oil)	1E1 Chiller (Electricity)	1E1 Total (Energy)	1E2 Heat Generation (Oil)	1E2 Chiller (Electricity)	1E2 Total (Energy)	1E3 Heat Generation (Oil)	1E3 Chiller (Electricity)	1E3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.51579	5.8627E-05	17.51579	12.06923	0.001405	12.07	11.09646	0.00132148	11.0976
2/1/2002	8.615029	13.40852	0.01876141	13.42728	5.149317	0.0507567	5.200011	8.315826	0.0650329	8.401921
3/1/2002	9.745699	12.31858	0.1243157	12.4429	8.715623	0.2497819	8.965404	8.108101	0.2625803	8.37060
4/1/2002	13.88528	4.354151	2.722891	7.080096	2.987207	3.322159	6.292165	2.800297	3.518402	6.318299
5/1/2002	19.40779	0.017908	13.10160	13.11908	0.02229568	13.92716	13.97066	0.01956622	14.13060	14.15051
6/1/2002	20.98195	0.002441595	18.06561	18.07217	0.001948158	18.51256	18.53441	0.00122902	18.66001	18.66053
7/1/2002	22.73441	0	34.17265	34.17265	0	34.02925	34.02925	0	34.0517	34.0517
8/1/2002	23.04382	0	33.54076	33.54076	0	33.29125	33.29125	0	33.30717	33.30717
9/1/2002	21.49319	0.000154006	26.77021	26.77036	5.5718E-05	27.29802	27.29808	3.8609E-05	27.44056	27.441
10/1/2002	19.88199	0.01258047	19.01185	19.02443	0.005058491	20.4412	20.44625	0.00422752	20.75961	20.76381
11/1/2002	14.60778	0.8185514	3.456108	4.274655	0.7161508	4.574401	5.290555	0.2645608	5.3171	5.581561
12/1/2002	9.495833	13.75121	0.2748895	14.02986	5.308567	0.5514974	5.862064	8.56026	0.6576716	9.238029
		67.22966086	151.86403	219.09367	42.56178807	156.64805	199.2606	38.91156108	158.31907	197.2411

Building One 20% WWR No Shading

Date	Outside Temperature °C	2C1 Heat Generation (Oil) KWh/m2	2C1 Chiller (Electricity) KWh/m2	2C1 Total (Energy) KWh/m2	2C2 Heat Generation (Oil) KWh/m2	2C2 Chiller (Electricity) KWh/m2	2C2 Total (Energy) KWh/m2	2C3 Heat Generation (Oil) KWh/m2	2C3 Chiller (Electricity) KWh/m2	2C3 Total (Energy) KWh/m2
1/1/2002	8.013307	17.31626	9.9635E-05	17.31636	11.90577	0.00087204	11.9066	10.89501	0.00147753	10.8965
2/1/2002	8.615029	13.25932	0.01833245	13.27765	9.089398	0.05025813	9.08966	8.23368	0.06302748	8.30071
3/1/2002	9.745099	12.16589	0.1217204	12.28761	8.626285	0.2399759	8.86626	7.911383	0.2833147	8.1949
4/1/2002	13.88528	4.28924	2.700573	6.989813	2.912063	3.278005	6.19007	2.649081	3.467056	6.11674
5/1/2002	19.40779	0.03681281	13.23448	13.27129	0.0224897	13.81929	13.8418	0.01998013	14.01561	14.0356
6/1/2002	20.98195	0.002414872	17.98103	17.98344	0.001439896	18.40204	18.4035	0.001222358	18.54815	18.5494
7/1/2002	22.73441	0	34.22165	34.22165	0	33.83021	33.8302	0	33.8508	33.8508
8/1/2002	23.04382	0	33.39591	33.39591	0	33.10487	33.1049	0	33.11157	33.1116
9/1/2002	21.49319	0.000134199	26.62692	26.62705	4.90637E-05	27.10317	27.1032	3.21867E-05	27.24711	27.2471
10/1/2002	19.88199	0.01248444	18.89997	18.91245	0.00490318	20.28421	20.2891	0.004037963	20.59165	20.5957
11/1/2002	14.60778	0.8009208	3.434761	4.235682	0.3133296	4.925756	5.23909	0.2616256	5.321465	5.58309
12/1/2002	9.495833	13.38365	0.2757547	13.6594	9.163854	0.5900385	9.75389	8.410311	0.6945648	9.10488
		61.46712712	150.911201	212.3783	41.90458144	155.634606	197.629	38.38016324	157.197796	195.587

Building One 20% WWR No Shading

Date	Outside Temperature °C	2E1 Heat Generation (Oil) kWh/m2	2E1 Chiller (Electricity) kWh/m2	2E1 Total (Energy) kWh/m2	2E2 Heat Generation (Oil) kWh/m2	2E2 Chiller (Electricity) kWh/m2	2E2 Total (Energy) kWh/m2	2E3 Heat Generation (Oil) kWh/m2	2E3 Chiller (Electricity) kWh/m2	2E3 Total (Energy) kWh/m2
1/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
8/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
9/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Building One 20% with Shading

Date	Outside Temperature °C	1C1 Heat Generation (Oil) kWh/m2	1C1 Chiller (Electricity) kWh/m2	1C1 Total (Energy) kWh/m2	1C2 Heat Generation (Oil) kWh/m2	1C2 Chiller (Electricity) kWh/m2	1C2 Total (Energy) kWh/m2	1C3 Heat Generation (Oil) kWh/m2	1C3 Chiller (Electricity) kWh/m2	1C3 Total (Energy) kWh/m2
1/1/2002	[illegible]	[illegible]	0	[illegible]	15.12065	0	15.12065	14.15187	0	14.15187
2/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
8/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
9/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Building One 20% with Shading

Date	Outside Temperature	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	1E2 Heat Generation (Oil)	1E2 Chiller (Electricity)	1E2 Total (Energy)	1E3 Heat Generation (Oil)	1E3 Chiller (Electricity)	1E3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	19.49163	0	19.49163	14.15418	1.4911E-05	14.15419	13.13477	7.8117E-05	13.13485
2/1/2002	8.615029	15.13888	0.00729806	15.14617	10.97718	0.02498071	11.00114	10.18077	0.03297553	10.21675
3/1/2002	9.745089	14.14715	0.06975456	14.21695	10.70057	0.1561571	10.85673	9.978602	0.1879156	10.16615
4/1/2002	13.88528	5.21736	2.32296	7.540305	3.805583	2.851091	6.657022	3.572514	2.972003	6.549817
5/1/2002	19.40775	0.0704271	12.74158	12.81272	0.0441541	13.2912	13.33536	0.0359803	13.49949	13.53504
6/1/2002	20.98195	0.00240726	17.82748	17.82987	0.00091941	18.3077	18.3086	0.00082798	18.49106	18.49189
7/1/2002	22.73441	0	34.71202	34.71202	0	34.41173	34.41173	0	34.45105	34.45105
8/1/2002	23.04382	0	33.49807	33.49807	0	33.20174	33.20174	0	33.2146	33.2146
9/1/2002	21.49819	0.00021888	25.92919	25.92940	5.6721E-05	25.36616	25.36622	2.1292E-05	25.4951	25.49512
10/1/2002	19.88199	0.0186014	18.06812	18.08672	0.00867582	19.29786	19.30671	0.00652956	19.58081	19.58733
11/1/2002	14.00778	1.109115	2.83692	3.945055	0.5145088	4.011028	4.52551	0.4525123	4.347645	4.80022
12/1/2002	9.495833	15.29946	0.185171	15.48464	10.84272	0.4191758	11.2622	10.08945	0.5012946	10.59074
		70.46878636	148.33138	218.80014	51.10207496	152.3227587	203.4247	47.52127471	153.768852	201.2901

Building One 20% with Shading

Date	Outside Temperature	2C1 Heat Generation (Oil)	2C1 Chiller (Electricity)	2C1 Total (Energy)	2C2 Heat Generation (Oil)	2C2 Chiller (Electricity)	2C2 Total (Energy)	2C3 Heat Generation (Oil)	2C3 Chiller (Electricity)	2C3 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	19.21721	0	19.21721	13.90258	2.7191E 05	13.9026	12.92745	0.0001419	12.9276
2/1/2002	8.615029	14.90349	0.00776108	14.91125	10.77335	0.02480967	10.7982	9.987233	0.03417566	10.0214
3/1/2002	9.745089	13.914	0.07048797	13.98449	10.49631	0.1570088	10.6533	9.804942	0.1905784	9.99552
4/1/2002	13.88528	5.094409	2.337668	7.432077	3.740165	2.821114	6.56128	3.478886	2.983894	6.46278
5/1/2002	19.40779	0.06790169	12.75966	12.82756	0.04281578	13.28367	13.3265	0.03839814	13.47528	13.5137
6/1/2002	20.98195	0.00236431	17.86243	17.86479	0.000922116	18.29693	18.2979	0.000660774	18.45334	18.454
7/1/2002	22.73441	0	34.70461	34.70461	0	34.35371	34.3537	0	34.38723	34.3872
8/1/2002	23.04382	0	33.48404	33.48404	0	33.16722	33.1672	0	33.17463	33.1746
9/1/2002	21.49819	0.000195766	26.00214	26.00234	4.70403E 05	26.34266	26.3427	1.44634E 05	26.46579	26.4658
10/1/2002	19.88199	0.01781692	18.09287	18.11069	0.006293824	19.29541	19.3017	0.00512563	19.57104	19.5762
11/1/2002	14.00778	1.069942	2.870065	3.940007	0.5173793	4.048816	4.5662	0.4494817	4.378911	4.82839
12/1/2002	9.495833	15.02875	0.1918128	15.22056	10.64607	0.430852	11.0769	9.899854	0.5136622	10.4135
		69.31607969	148.389545	217.7056	50.12503306	152.222283	202.348	46.59204573	153.628673	200.221

Building One 20% with Shading

Date	Outside Temperature	1I1 Heat Generation (Oil)	1I1 Chiller (Electricity)	1I1 Total (Energy)	1I2 Heat Generation (Oil)	1I2 Chiller (Electricity)	1I2 Total (Energy)	1I3 Heat Generation (Oil)	1I3 Chiller (Electricity)	1I3 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	18.77406	0	18.77406	13.42605	9.9092E 05	13.4261	12.43661	0.00034788	12.437
2/1/2002	8.615029	14.52322	0.00899536	14.53222	10.35353	0.02904947	10.3826	9.568628	0.03988032	9.60851
3/1/2002	9.745089	13.52102	0.08031712	13.60134	10.07257	0.1770364	10.2496	9.372947	0.2139868	9.58693
4/1/2002	13.88528	4.887637	2.442363	7.33	3.533082	2.962677	6.49576	3.273078	3.137783	6.41086
5/1/2002	19.40779	0.06130001	13.01634	13.07764	0.03871076	13.57797	13.6167	0.03474057	13.77717	13.8119
6/1/2002	20.98195	0.002074332	18.12021	18.12228	0.000724443	18.57786	18.5786	0.000510226	18.73996	18.7405
7/1/2002	22.73441	0	34.98052	34.98052	0	34.64947	34.6495	0	34.68084	34.6809
8/1/2002	23.04382	0	33.77006	33.77006	0	33.47166	33.4717	0	33.48277	33.4828
9/1/2002	21.49819	0.000156678	26.27529	26.27545	1.62465E 05	26.64021	26.6402	0	26.70936	26.7094
10/1/2002	19.88199	0.0157776	18.31155	18.32733	0.00557226	19.54676	19.5523	0.004526822	19.82712	19.8316
11/1/2002	14.00778	1.00848	2.983145	3.991625	0.4782601	4.227419	4.70568	0.4160769	4.57809	4.99417
12/1/2002	9.495833	14.67348	0.2101667	14.88365	10.27513	0.4698125	10.7449	9.5189	0.5602717	10.0792
		67.46720562	150.198057	217.6662	48.18364581	154.330023	202.514	44.62001752	155.813688	200.44

Building One 40% No Shading

Date	Outside Temperature	1C1 Heat Generation (Oil)	1C1 Chiller (Electricity)	1C1 Total (Energy)	1C2 Heat Generation (Oil)	1C2 Chiller (Electricity)	1C2 Total (Energy)	1C3 Heat Generation (Oil)	1C3 Chiller (Electricity)	1C3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	18.3145	0.00107787	18.3176	13.35176	0.001744951	13.3615	12.45119	0.001386141	12.4249
2/1/2002	8.615029	13.7159	0.05749955	13.7757	9.878551	0.1151191	9.99367	9.180659	0.1365095	9.31716
3/1/2002	9.745829	13.10677	0.2227785	13.3345	9.501557	0.1720121	10.2236	9.270703	0.419814	9.69052
4/1/2002	13.88528	4.897089	3.114253	8.01112	3.868605	3.695346	7.30076	3.171301	3.870227	7.04553
5/1/2002	19.40771	0.05880983	13.75909	13.8176	0.008302743	14.37982	14.4081	0.00254951	14.57886	14.5814
6/1/2002	20.96195	0.002782271	18.41256	18.4156	0.001125788	18.91602	18.9173	0.000291459	19.07528	19.0753
7/1/2002	22.73441	0	35.71809	35.718	0	35.51742	35.5174	0	35.56614	35.5661
8/1/2002	21.84382	0	35.82703	35.8279	0	35.77077	35.7708	0	35.80198	35.8012
9/1/2002	21.47319	0.000298011	29.81265	29.8129	0.000111467	30.35925	30.3593	2.07954E-05	30.54817	30.5481
10/1/2002	19.86179	0.01485125	22.21291	22.25	0.006402954	23.82885	23.8356	0.00519506	24.16519	24.1706
11/1/2002	14.60748	0.755383	4.780712	5.5306	0.4551129	6.55701	7.01612	0.4000381	6.759475	7.15951
12/1/2002	9.449833	14.61019	0.4567574	15.0773	10.55619	0.634211	11.1906	9.807854	0.7015591	10.5034
		86.67722287	164.4090174	250.116	47.80867454	170.1442493	218.205	44.81578167	172.1267049	216.342

Building One 40% No Shading

Date	Outside Temperature	1E1 Heat Generation (Oil)	1E1 Chiller (Electricity)	1E1 Total (Energy)	1E2 Heat Generation (Oil)	1E2 Chiller (Electricity)	1E2 Total (Energy)	1E3 Heat Generation (Oil)	1E3 Chiller (Electricity)	1E3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2010	8.013307	17.30112	0.004268221	17.3054	12.13175	0.0164	12.1482	11.19975	0.02354289	11.2233
2/1/2010	8.615029	12.90541	0.009101011	12.9144	8.806913	0.1172678	8.92418	8.087215	0.1482721	8.23694
3/1/2010	9.745829	12.25184	0.2610151	12.5165	8.829574	0.4513277	9.2809	8.147289	0.5172086	8.66449
4/1/2010	13.88528	4.489584	3.317898	7.8074	3.159075	4.148427	7.30751	2.906831	4.277115	7.1784
5/1/2010	19.40771	0.01474747	14.19889	14.2449	0.0298	14.96575	14.9956	0.02661821	15.19126	15.2179
6/1/2010	20.96195	0.002180292	18.82703	18.8248	0.00165	19.47208	19.4745	0.00106878	19.85041	19.851
7/1/2010	22.73441	0	36.11425	36.1143	0	35.92708	35.9271	0	36.01862	36.0186
8/1/2010	21.84382	0	36.15715	36.1572	0	36.15775	36.1577	0	36.21049	36.2105
9/1/2010	21.47319	0.00021161	30.01859	30.0188	0.0000577	30.80171	30.8018	2.2904E-05	31.01881	31.0188
10/1/2010	19.86179	0.0110758	22.56945	22.5805	0.00515	24.30845	24.3116	0.00199259	24.67471	24.675
11/1/2010	14.60748	0.8245137	5.258441	6.0925	0.386831	7.050832	7.43766	0.3303518	7.534722	7.86507
12/1/2010	9.449833	13.47129	0.802111	14.2837	9.557215	0.7108525	10.5881	8.897555	1.131086	10.0287
		61.51961309	167.3717235	228.841	42.9400867	174.4520417	217.347	39.57204911	176.4641731	216.036

Building One 40% No Shading

Date	Outside Temperature	2C1 Heat Generation (Oil)	2C1 Chiller (Electricity)	2C1 Total (Energy)	2C2 Heat Generation (Oil)	2C2 Chiller (Electricity)	2C2 Total (Energy)	2C3 Heat Generation (Oil)	2C3 Chiller (Electricity)	2C3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.14137	0.00110875	12.1455	12.04751	0.0135482	12.0612	11.13185	0.01725791	11.1511
2/1/2002	8.615029	12.76098	0.05840825	12.8214	8.838861	0.1313012	8.96719	8.100112	0.158845	8.25897
3/1/2002	9.745829	12.16175	0.219195	12.401	8.825319	0.4107155	9.23605	8.186021	0.4865154	8.67277
4/1/2002	13.88528	4.442465	3.17119	7.61658	3.140109	3.85277	6.99287	2.902347	4.001447	6.90359
5/1/2002	19.40771	0.04885879	13.88252	13.9181	0.01100	14.54427	14.5553	0.02771747	14.74809	14.7756
6/1/2002	20.96195	0.002145515	18.50198	18.5041	0.000880	19.0068	19.0077	0.001042837	19.16508	19.1657
7/1/2002	22.73441	0	35.58183	35.581	0	35.34018	35.3402	0	35.38177	35.38177
8/1/2002	21.84382	0	35.62279	35.623	0	35.52495	35.5249	0	35.55796	35.55796
9/1/2002	21.47319	0.000175159	29.50025	29.5014	4.10517E-05	30.21487	30.2149	1.5795E-05	30.40006	30.4001
10/1/2002	19.86179	0.01303545	22.13808	22.1455	0.009081772	23.76507	23.7741	0.00189725	24.11081	24.1125
11/1/2002	14.60748	0.8205315	5.089815	5.91017	0.3818783	6.81374	7.19785	0.309855	7.240171	7.55713
12/1/2002	9.449833	13.57382	0.5051184	14.0792	9.472083	0.7085625	10.4172	8.791418	1.069296	9.86071
		60.98256401	164.2760311	225.242	42.74465861	170.5178017	211.262	39.45974865	172.4408	211.8298

Building One 40% No Shading

Date	Outside Temperature	211 Heat Generation (Oil)	211 Chiller (Electricity)	211 Total (Energy)	212 Heat Generation (Oil)	212 Chiller (Electricity)	212 Total (Energy)	213 Heat Generation (Oil)	213 Chiller (Electricity)	213 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	16.72793	0.00448004	16.7325	11.57242	0.01487939	11.5873	10.64208	0.02139039	10.66347
2/1/2002	8.615029	12.43149	0.06206107	12.4936	8.442745	0.1361809	8.57893	7.702616	0.1068167	7.809433
3/1/2002	9.745099	11.81136	0.2442278	12.0556	8.418637	0.4280238	8.84666	7.748708	0.4904237	8.239132
4/1/2002	13.88528	4.258101	3.231976	7.49008	2.956324	3.936791	6.89312	2.717583	4.158386	6.875969
5/1/2002	19.40779	0.04462418	14.01201	14.0566	0.02887799	14.7181	14.747	0.02588982	14.93306	14.95895
6/1/2002	20.98195	0.001942364	18.05219	18.0541	0.000722634	19.17393	19.1747	0.000527883	19.33844	19.33897
7/1/2002	22.73441	0	35.09622	35.0962	0	35.4607	35.4607	0	35.3087	35.3087
8/1/2002	23.04382	0	35.67618	35.6762	0	35.57392	35.5739	0	35.61901	35.61901
9/1/2002	21.49319	0.000155386	29.52563	29.5258	1.79057E-05	30.23755	30.2376	9.95874E-06	30.42471	30.42471
10/1/2002	19.88199	0.01214708	22.08586	22.098	0.004398737	23.73487	23.7393	0.003346799	24.03589	24.03924
11/1/2002	14.60778	0.7746329	5.078717	5.85335	0.3561611	6.895809	7.25197	0.3073493	7.339725	7.647074
12/1/2002	9.495833	13.21678	0.5139019	13.7307	9.09407	0.9738083	10.0679	8.39472	1.11434	9.50906
		59.27921201	164.78346	224.063	40.87437437	171.286623	212.161	37.5428209	173.200892	210.7437

Building One 40% with Shading

Date	Outside Temperature	101 Heat Generation (Oil)	101 Chiller (Electricity)	101 Total (Energy)	102 Heat Generation (Oil)	102 Chiller (Electricity)	102 Total (Energy)	103 Heat Generation (Oil)	103 Chiller (Electricity)	103 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	20.78226	0	20.7823	15.84016	0	15.84016	14.93351	0	14.93351
2/1/2002	8.615029	16.2478	6.58E-03	16.2544	12.35808	0.01843993	12.37652	11.66048	0.02472032	11.6852
3/1/2002	9.745099	15.4208	4.79E-02	15.4687	12.27483	0.1040093	12.3789	11.65109	0.1260827	11.77717
4/1/2002	13.88528	6.041028	2.005543	8.04657	4.747555	2.343796	7.091351	4.503915	2.400362	6.904277
5/1/2002	19.40779	0.1040045	11.58905	11.6931	0.07150251	11.93336	12.00486	0.06418792	12.07761	12.1418
6/1/2002	20.98193	3.40E-03	16.49139	16.4948	0.001618842	16.78303	16.78665	0.001193942	16.9068	16.90799
7/1/2002	22.73441	0	33.07449	33.0745	0	32.63632	32.63632	0	32.64628	32.64628
8/1/2002	23.04382	0	32.32083	32.3209	0	31.96463	31.96463	0	31.96272	31.96272
9/1/2002	21.49319	2.86E-04	25.22717	25.2275	0.000110673	25.52066	25.52677	7.82150E-05	25.63557	25.63565
10/1/2002	19.88199	2.28E-02	17.95266	17.9755	0.008320834	19.08776	19.0961	0.006382325	19.3435	19.35038
11/1/2002	14.60778	1.317465	2.833426	4.15089	0.6889716	3.843375	4.532347	0.6033718	4.112803	4.716175
12/1/2002	9.495833	16.41285	0.1621245	16.575	12.22304	0.346083	12.57412	11.54023	0.4099451	11.95018
		76.35271177	141.711171	218.064	58.21918946	144.580544	202.8087	54.9649392	145.706303	200.6713

Building One 40% with Shading

Date	Outside Temperature	111 Heat Generation (Oil)	111 Chiller (Electricity)	111 Total (Energy)	112 Heat Generation (Oil)	112 Chiller (Electricity)	112 Total (Energy)	113 Heat Generation (Oil)	113 Chiller (Electricity)	113 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	19.54637	0	19.5464	14.35256	9.9821E-05	14.35266	13.41232	0.00022279	13.41254
2/1/2002	8.615029	15.15015	0.01074325	15.1609	11.1233	0.03066396	11.15397	10.36873	0.04068323	10.40941
3/1/2002	9.745099	14.36499	0.0700683	14.4351	11.03198	0.1526656	11.18465	10.3686	0.1832486	10.55185
4/1/2002	13.88528	5.508187	2.217317	7.7255	4.154943	2.661897	6.81684	3.894298	2.808643	6.702941
5/1/2002	19.40779	0.07961524	12.12023	12.1998	0.04895225	12.59724	12.64619	0.0433585	12.77109	12.81445
6/1/2002	20.98193	0.002300405	17.09043	17.093	0.000913442	17.48862	17.48953	0.000634901	17.63336	17.63399
7/1/2002	22.73441	0	33.70868	33.7087	0	33.34433	33.34433	0	33.37242	33.37242
8/1/2002	23.04382	0	32.90788	32.9079	0	32.60588	32.60588	0	32.6162	32.6162
9/1/2002	21.49319	0.000211747	25.90627	25.9063	5.78089E-05	26.29806	26.29812	2.28387E-05	26.43117	26.43119
10/1/2002	19.88199	0.01805861	18.54919	18.5672	0.006501441	19.84005	19.84655	0.00525449	20.13273	20.13798
11/1/2002	14.60778	1.124623	3.144207	4.26883	0.5346708	4.38358	4.918257	0.4693133	4.710992	5.180305
12/1/2002	9.495833	15.35368	0.2139792	15.5677	11.05561	0.4600683	11.51568	10.33889	0.5425933	10.88148
		71.148396	145.930035	217.087	52.30040474	149.863157	202.1727	48.80542203	151.240353	200.1448

Building One 40% with Shading

Date	Outside Temperature	2C1 Heat Generation (Oil)	2C1 Chiller (Electricity)	2C1 Total (Energy)	2C2 Heat Generation (Oil)	2C2 Chiller (Electricity)	2C2 Total (Energy)	2C3 Heat Generation (Oil)	2C3 Chiller (Electricity)	2C3 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	19.13176	0	19.13176	14.00482	0.00026209	14.00508	13.08108	0.00046581	13.081546
2/1/2002	8.615029	14.81008	0.01178049	14.82186	10.84749	0.03253542	10.88003	10.10588	0.04286149	10.148741
3/1/2002	9.743699	14.04272	0.06952983	14.11225	10.76461	0.1510575	10.91567	10.11473	0.180994	10.295724
4/1/2002	13.88528	5.341796	2.218326	7.560122	4.022433	2.047299	6.069732	3.772136	2.79027	6.562406
5/1/2002	19.40779	0.07587189	12.08754	12.16341	0.04741209	12.52182	12.56923	0.04222852	12.68555	12.727779
6/1/2002	20.98195	0.002417207	17.01143	17.01385	0.000941094	17.36275	17.36369	0.000673294	17.50002	17.500693
7/1/2002	22.73441	0	33.58463	33.58463	0	33.17294	33.17294	0	33.19151	33.19151
8/1/2002	23.04382	0	32.8053	32.8053	0	32.40422	32.40422	0	32.47018	32.47018
9/1/2002	21.49319	0.000195594	25.85659	25.85679	4.84202E-05	26.20108	26.20113	1.52337E-05	26.32372	26.323735
10/1/2002	19.88199	0.01675966	18.36053	18.37729	0.006279262	19.80259	19.80887	0.004854526	20.0821	20.080955
11/1/2002	14.60778	1.07043	3.202722	4.273152	0.5130228	4.432003	4.945026	0.4474185	4.758969	5.2063875
12/1/2002	9.493833	15.00968	0.2261094	15.23583	10.77937	0.4768761	11.25625	10.07558	0.559864	10.635444
		69.50170935	145.634547	215.1363	50.98642727	140.265433	200.2519	47.64450608	150.586504	198.2311

Building One 40% with Shading

Date	Outside Temperature	2E1 Heat Generation (Oil)	2E1 Chiller (Electricity)	2E1 Total (Energy)	2E2 Heat Generation (Oil)	2E2 Chiller (Electricity)	2E2 Total (Energy)	2E3 Heat Generation (Oil)	2E3 Chiller (Electricity)	2E3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	18.59069	[illegible]	18.59072	13.35625	0.00061009	13.35786	12.41611	0.00095051	12.41706
2/1/2002	8.615029	14.30412	0.01102057	14.31519	10.30258	0.02215412	10.32473	9.515896	0.0515062	9.567402
3/1/2002	9.743699	13.53891	0.08848825	[illegible]	10.30022	0.1707126	10.47093	9.51??	0.2106??	[illegible]
4/1/2002	13.88528	[illegible]	2.325866	[illegible]	3.742002	2.710688	[illegible]	[illegible]	2.754205	[illegible]
5/1/2002	19.40779	0.06520115	12.36132	12.42652	0.04057251	12.84416	12.88501	0.03689091	13.01972	13.05661
6/1/2002	20.98195	0.00258142	17.29869	17.29869	0.00072617	17.662	17.6627	0.00051126	17.82555	17.82601
7/1/2002	22.73441	0	33.59117	33.59117	0	33.50172	33.50172	0	33.57514	33.57514
8/1/2002	23.04382	0	33.07851	33.07851	0	32.75442	32.75442	0	32.78825	32.78825
9/1/2002	21.49319	0.000154721	25.13805	25.1382	1.4051E-05	25.51152	25.51154	0	25.64158	25.64158
10/1/2002	19.88199	0.0119xxxx	18.7767	18.7xx8	0.00525817	20.08285	20.08811	0.00421175	20.35101	20.35522
11/1/2002	14.60778	0.7090603	3.314536	4.025173	0.4640555	4.657291	5.12185	0.4091061	5.011423	5.416592
12/1/2002	9.493833	14.51525	0.2513088	14.7xx8	10.26551	0.530219	10.79563	9.54?11	0.622?1	10.1??
		67.06541146	147.548545	214.544	48.35463121	151.534898	199.9187	44.97?086	152.97??	197.9??

Building One 100% No Shading

Date	Outside Temperature	1C1 Heat Generation (Oil)	1C1 Chiller (Electricity)	1C1 Total (Energy)	1C2 Heat Generation (Oil)	1C2 Chiller (Electricity)	1C2 Total (Energy)	1C3 Heat Generation (Oil)	1C3 Chiller (Electricity)	1C3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	18.51079	0.27621	18.7888	12.30185	0.4120011	12.71385	11.62625	0.4405621	12.06681
2/1/2002	8.615029	11.81407	0.5186211	12.33269	8.698416	0.706811	9.405271	8.159848	0.7515591	8.911405
3/1/2002	9.743699	11.57152	0.9531417	12.5248	8.844646	1.2058	10.05045	8.145117	1.269103	9.41422
4/1/2002	13.88528	4.490814	5.01?6??	9.52761	3.348646	5.712238	9.06107?	3.108863	5.883529	9.0?2??
5/1/2002	19.40779	0.0172168	16.47514	16.5?61	0.01002?27	17.18212	17.19215	0.0099?113	17.31852	17.3?845
6/1/2002	20.98195	0.0027?452	20.72??4	20.731	0.0013?5?8	21.?0917	21.?498	0.0010?5??	21.3?9?1	21.38?4
7/1/2002	22.73441	0	39.12468	39.1?1?	0	39.07?03	39.07?03	0	39.13308	39.13308
8/1/2002	23.04382	0	40.29?85	40.29??	0	40.49?13	40.49?13	0	40.55856	40.55856
9/1/2002	21.49319	0.0002?5?7?	35.31885	35.3??	0.0001?2?75	35.?0?5?	35.?1??	7.?85E-05	35.50?5?	35.50??
10/1/2002	19.88199	0.01?9?6??	30.55101	30.56?	0.008?8??	30.3?2?8	30.36??	0.0060?5155	30.70?48	30.71??
11/1/2002	14.60778	0.826?5?8	9.012?16	9.8?88	0.4080?9?	10.7461?	11.15?28	0.35?4182	11.1071?	11.46?9?
12/1/2002	9.493833	13.47155	1.4?061	14.9?22	9.7?6577	2.01?2?4	12.0?1?4	9.458?85	2.11?5?	11.5?8?5
		50.82?01?76	197.78?611	256.644	41.69?8??	205.40?88	249.1?0?	41.1625?112	207.2??5?1	248.38?1

Building One 100% No Shading

Date	Outside Temperature	1E1 Heat Generation (Oil)	1E1 Chiller (Electricity)	1E1 Total (Energy)	1E2 Heat Generation (Oil)	1E2 Chiller (Electricity)	1E2 Total (Energy)	1E3 Heat Generation (Oil)	1E3 Chiller (Electricity)	1E3 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	14.55465	0.4105483	14.9654	10.15808	0.6633837	10.82147	9.422995	0.7283825	10.15138
2/1/2002	8.615029	10.28309	0.7163321	10.9994	7.010047	1.083592	8.093639	6.451407	1.174807	7.626214
3/1/2002	9.745099	9.880932	1.240437	11.1274	6.913524	1.686827	8.600351	6.380163	1.798319	8.178482
4/1/2002	13.88528	3.735109	5.828081	9.56323	2.602337	6.869492	9.471829	2.408667	7.12066	9.529327
5/1/2002	19.40779	0.03843689	17.67716	17.7156	0.02295009	18.62917	18.65212	0.02017606	18.85499	18.87517
6/1/2002	20.98195	0.002270339	21.90958	21.9119	0.000890607	22.62433	22.62522	0.000615901	22.79358	22.7943
7/1/2002	22.73441	0	40.21137	40.2114	0	40.32571	40.32571	0	40.41052	40.41052
8/1/2002	23.04382	0	41.28313	41.2831	0	41.63098	41.63098	0	41.74151	41.74151
9/1/2002	21.49319	0.000213207	36.50896	36.5092	5.83607E 05	37.73102	37.73108	2.34776E 05	37.9803	37.98032
10/1/2002	19.88199	0.01339836	29.7427	29.7561	0.004935613	31.90716	31.9121	0.003829136	32.31367	32.3173
11/1/2002	14.60778	0.6581165	10.12803	10.7861	0.3050843	12.38847	12.69355	0.2598026	12.85148	13.11128
12/1/2002	9.495833	11.80525	1.878526	13.6838	8.205348	2.671618	10.87697	7.640761	2.852347	10.49311
		50.9777283	207.534854	258.513	35.22325407	218.217755	253.441	32.58844019	220.620866	253.2093

Building One 100% No Shading

Date	Outside Temperature	2C1 Heat Generation (Oil)	2C1 Chiller (Electricity)	2C1 Total (Energy)	2C2 Heat Generation (Oil)	2C2 Chiller (Electricity)	2C2 Total (Energy)	2C3 Heat Generation (Oil)	2C3 Chiller (Electricity)	2C3 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	14.53248	0.3396845	14.8722	10.24848	0.5410879	10.78957	9.535279	0.5932999	10.1286
2/1/2002	8.615029	10.33793	0.6077724	10.9457	7.126198	0.8982421	8.02444	6.570818	0.9726811	7.5435
3/1/2002	9.745099	9.981346	1.054845	11.0362	7.109715	1.412257	8.521972	6.595477	1.503539	8.09902
4/1/2002	13.88528	3.747238	5.252892	9.00013	2.648886	6.117531	8.766417	2.463139	6.334739	8.79788
5/1/2002	19.40779	0.03860475	16.73752	16.7761	0.02453829	17.50896	17.5335	0.02167587	17.7058	17.7275
6/1/2002	20.98195	0.002139753	20.91651	20.9187	0.000894132	21.47198	21.47287	0.000633995	21.6137	21.6143
7/1/2002	22.73441	0	38.88307	38.8851	0	38.8194	38.8194	0	38.87504	38.875
8/1/2002	23.04382	0	39.95237	39.9524	0	40.13179	40.13179	0	40.20774	40.2077
9/1/2002	21.49319	0.000196353	35.22895	35.2291	4.86757E 05	36.2672	36.26725	1.60843E 05	36.48717	36.4872
10/1/2002	19.88199	0.01258911	28.61536	28.6279	0.004610526	30.56664	30.57125	0.003381076	30.93903	30.9426
11/1/2002	14.60778	0.6543493	9.474287	10.1286	0.3084187	11.5345	11.84292	0.264109	11.96303	12.2271
12/1/2002	9.495833	11.74828	1.699925	13.4482	8.248253	2.400393	10.64865	7.700566	2.561591	10.2622
		51.05517347	198.765186	249.82	35.72004232	207.669081	243.39	33.15529503	209.75736	242.913

Building One 100% No Shading

Date	Outside Temperature	2E1 Heat Generation (Oil)	2E1 Chiller (Electricity)	2E1 Total (Energy)	2E2 Heat Generation (Oil)	2E2 Chiller (Electricity)	2E2 Total (Energy)	2E3 Heat Generation (Oil)	2E3 Chiller (Electricity)	2E3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
8/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
9/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Building One 100% With Shading

Date	Outside Temperature	1C1 Heat Generation (Oil)	1C1 Chiller (Electricity)	1C1 Total (Energy)	1C2 Heat Generation (Oil)	1C2 Chiller (Electricity)	1C2 Total (Energy)	1C3 Heat Generation (Oil)	1C3 Chiller (Electricity)	1C3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	20.35059	0.0085059	20.3511	15.87721	0.0026249	15.8801	15.12857	0.00410821	15.13278
2/1/2002	8.613029	15.47482	0.0530185	15.5277	12.02647	0.0768686	12.1033	11.44986	0.0884552	11.5383
3/1/2002	9.745699	15.05702	0.1201502	15.1772	12.32549	0.188236	12.5112	11.82091	0.2111052	12.0321
4/1/2002	13.88528	6.08126	2.491077	8.5755	4.951409	2.801144	7.251148	4.793054	2.508125	7.30117
5/1/2002	19.40779	0.1222152	12.13456	12.2558	0.09123017	12.4181	12.5188	0.06768961	12.55158	12.6196
6/1/2002	20.98195	0.005711144	16.78957	16.7954	0.002481113	17.00274	17.0054	0.002107171	17.06803	17.0704
7/1/2002	22.73441	0	31.72649	31.7265	0	33.31965	33.31965	0	33.3197	33.3197
8/1/2002	23.04382	0	31.74051	31.7405	0	33.49408	33.49408	0	33.50821	33.5082
9/1/2002	21.49319	0.000185272	27.92248	27.9241	0.000118155	28.40208	28.4022	8.37868E-05	28.51411	28.5142
10/1/2002	19.85199	0.0284211	21.10708	21.1145	0.002902217	22.15004	22.1571	0.005876857	22.81258	22.8186
11/1/2002	14.60778	1.257483	4.47867	5.7367	0.6713818	5.603267	6.275151	0.6178868	5.866215	6.484102
12/1/2002	9.485833	16.27305	0.5305986	16.8036	12.57453	0.6222138	13.2068	12.10752	0.880003	12.9865
		71.86824172	152.941467	224.81	50.53127401	158.304086	214.8606	55.86918621	157.176717	213.2458

Building One 100% With Shading

Date	Outside Temperature	1E1 Heat Generation (Oil)	1E1 Chiller (Electricity)	1E1 Total (Energy)	1E2 Heat Generation (Oil)	1E2 Chiller (Electricity)	1E2 Total (Energy)	1E3 Heat Generation (Oil)	1E3 Chiller (Electricity)	1E3 Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	17.9341	0.00617029	17.9403	13.26153	0.02116325	13.28269	12.48105	0.02794736	12.509
2/1/2002	8.613029	13.40738	0.08029135	13.3537	9.849616	0.1505351	10.00013	9.217988	0.1713087	9.389297
3/1/2002	9.745699	13.12379	0.2033099	13.3272	10.10952	0.3286619	10.43818	9.549989	0.3659131	9.915902
4/1/2002	13.88528	5.12085	2.934901	8.05575	3.902671	3.425282	7.327953	3.680974	3.56957	7.250544
5/1/2002	19.40779	0.07417127	13.15408	13.2289	0.04784277	13.6306	13.69644	0.04284408	13.80184	13.84468
6/1/2002	20.98195	0.002360747	17.89596	17.8983	0.000860436	18.2609	18.26177	0.000399631	18.37589	18.37649
7/1/2002	22.73441	0	34.83733	34.8373	0	34.53007	34.53007	0	34.55018	34.55018
8/1/2002	23.04382	0	34.78908	34.7891	0	34.04268	34.04268	0	34.06843	34.06843
9/1/2002	21.49319	0.000216499	29.19864	29.1989	6.26048E 05	29.85683	29.85689	2.72707E 05	30.02229	30.02232
10/1/2002	19.85199	0.01495536	22.35708	22.3726	0.00527586	23.91364	23.91892	0.004118314	24.23038	24.2345
11/1/2002	14.60778	0.9329633	5.341602	6.27457	0.438321	6.87447	7.312791	0.3810926	7.224503	7.605596
12/1/2002	9.485833	14.29539	0.5879881	14.8834	10.45671	0.9717829	11.42849	9.85538	1.075789	10.93137
		64.96617938	161.393093	226.36	48.07241547	166.626115	214.0985	45.22026285	168.084041	213.3043

Building One 100% With Shading

Date	Outside Temperature	2C1 Heat Generation (Oil)	2C1 Chiller (Electricity)	2C1 Total (Energy)	2C2 Heat Generation (Oil)	2C2 Chiller (Electricity)	2C2 Total (Energy)	2C3 Heat Generation (Oil)	2C3 Chiller (Electricity)	2C3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.47701	0.0082295	17.4862	12.95581	0.0221762	12.9780	12.18825	0.0282783	12.2155
2/1/2002	8.613029	13.12854	0.0884151	13.2168	9.643885	0.1490134	9.792918	9.059472	0.1686528	9.228125
3/1/2002	9.745699	12.79154	0.1912295	12.9828	9.905508	0.3097201	10.21558	9.312212	0.3442082	9.71652
4/1/2002	13.88528	4.955172	2.850095	7.80117	3.805521	3.300411	7.105932	3.600025	3.415761	7.01571
5/1/2002	19.40779	0.0712096	12.99211	13.0638	0.04757566	13.35162	13.4012	0.04292821	13.48867	13.5316
6/1/2002	20.98195	0.002275726	17.62807	17.6305	0.000900071	17.21352	17.21442	0.000646685	18.01428	18.0149
7/1/2002	22.73441	0	34.0578	34.0578	0	34.07256	34.07256	0	34.0715	34.0715
8/1/2002	23.04382	0	34.42915	34.425	0	34.20168	34.20168	0	34.21225	34.2123
9/1/2002	21.49319	0.000201548	28.90211	28.9011	5.36208E-05	29.4854	29.48545	1.73863E-05	29.81407	29.8141
10/1/2002	19.85199	0.0137868	22.17808	22.1925	0.0050675	23.81794	23.82251	0.003914112	23.51439	23.5181
11/1/2002	14.60778	0.8950875	5.308512	6.2156	0.4313292	6.788173	7.219405	0.1276859	7.12281	7.50017
12/1/2002	9.485833	13.90185	0.6022101	14.5046	10.10212	0.9680821	11.157	9.608811	1.096856	10.6755
		61.25728047	159.616702	222.844	46.97487572	164.160069	211.1407	44.22947417	165.496561	209.726

Building One 100% With Shading										
		2E1			2E2			2E3		
Date	Outside Temperature	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)
	°C	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2	KWh/m2
1/1/2002	8.013307	16.51378	0.01400932	16.5278	11.91626	0.03703028	11.95329	11.14152	0.04670081	11.1882
2/1/2002	8.615029	12.33393	0.1071168	12.441	8.787419	0.1848999	8.972319	8.17236	0.2100168	8.38238
3/1/2002	9.743699	11.99758	0.2347207	12.2323	9.018406	0.3749206	9.393327	8.467604	0.4165334	8.88414
4/1/2002	13.88528	4.555182	3.048484	7.60367	3.380919	3.561602	6.942521	3.170049	3.713348	6.8834
5/1/2002	19.40779	0.05614858	13.32624	13.3824	0.03642739	13.80058	13.83701	0.03292115	13.9504	13.9833
6/1/2002	20.98195	0.001990823	18.01772	18.0197	0.000703498	18.33958	18.34028	0.000502338	18.44938	18.4499
7/1/2002	22.73441	0	34.79827	34.7983	0	34.43855	34.43855	0	34.44992	34.4499
8/1/2002	23.04382	0	34.73028	34.7303	0	34.52714	34.52714	0	34.54631	34.5463
9/1/2002	21.49319	0.000161412	29.25138	29.2515	2.15585E-05	29.80017	29.80019	8.74305E-07	30.01699	30.017
10/1/2002	19.88199	0.01215711	22.49207	22.5042	0.004375122	24.01165	24.01603	0.003398758	24.32247	24.3259
11/1/2002	14.60778	0.793147	5.624015	6.41716	0.3727704	7.230086	7.602862	0.3252334	7.596873	7.92211
12/1/2002	9.493833	13.10326	0.6797447	13.783	9.36619	1.112379	10.47857	8.771852	1.226801	9.99865
		59.36734292	162.324051	221.691	42.88349796	167.478588	210.3621	40.00144152	168.945743	209.037

Table 72: Building Two South-East- Extended Results (monthly Data)

Building Two Base Case

Date/Time	System Misc	Heat Generation (Oil)	Chiller (Electricity)	DHW (Electricity)	Outside Temperature
	kWh/m2	kWh/m2	kWh/m2	kWh/m2	°C
37257	2.633346	16.87609	0.000141455	1.763052	8.013307
37288	2.915491	12.25375	0.01741216	1.559272	8.615029
37316	2.821442	10.70856	0.2169465	1.677382	9.745699
37347	2.915491	3.501961	3.665487	1.695126	13.88528
37377	2.821442	0.008434688	16.42946	1.763052	19.40779
37408	2.915491	0	21.50094	1.609455	20.98195
37438	2.915491	0	38.67777	1.763052	22.73441
37469	2.821442	0	37.15937	1.720217	23.04382
37500	2.915491	0	29.49896	1.65229	21.49319
37530	2.821442	0.01109828	20.07462	1.763052	19.88199
37561	2.915491	0.8027108	3.611553	1.65229	14.60778
37591	2.915491	13.54417	0.2681981	1.720217	9.495833
	34.327551	**57.70677477**	**171.1208582**	**20.338457**	

Building Two 20% No Shading

Date	Outside Temperature	1C1 Heat Generation (Oil)	1C1 Chiller (Electricity)	1C1 Total (Energy)	1C2 Heat Generation (Oil)	1C2 Chiller (Electricity)	1C2 Total (Energy)	1C3 Heat Generation (Oil)	1C3 Chiller (Electricity)	1C3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	14.85921	5.27E-04	14.8598	10.81575	0.00201367	10.8178	10.07195	[illegible]	10.07611
2/1/2002	8.615029	10.47242	7.25E-03	10.4799	7.540641	0.03654802	7.58715	6.962536	0.05786594	7.020401
3/1/2002	9.745699	9.051529	0.2351085	9.28667	6.636611	0.3659157	7.00221	6.121647	0.4101102	6.532057
4/1/2002	13.88528	2.874105	3.680201	6.55431	2.001461	4.354187	6.35567	1.813711	4.567086	6.400281
5/1/2002	19.40779	4.54E-03	15.80966	15.8142	0.00224068	15.86576	15.8682	0.00194757	16.30135	16.3033
6/1/2002	20.98195	0	20.53171	20.5317	0	21.29974	21.306	0	21.48535	21.48535
7/1/2002	22.73441	0	36.27715	36.2772	0	36.57198	36.54	0	36.6491	36.6491
8/1/2002	23.04382	0	34.84135	34.8414	0	34.80242	34.8024	0	34.90124	34.90124
9/1/2002	21.49319	0	27.50185	27.5019	0	26.22281	26.2228	0	28.40585	28.40585
10/1/2002	19.88199	0.00727916	18.87864	18.886	0.00271667	20.12451	20.1267	0.00178475	20.41821	20.42001
11/1/2002	14.60778	0.6402544	3.54104	4.18029	0.3096211	4.700854	5.01006	0.2670267	5.010094	5.277121
12/1/2002	9.495833	11.74404	0.3023082	12.0463	8.821121	0.4577494	9.2258	8.170176	0.5711979	8.741374
		49.50751146	161.4082...	210.916	36.06044062	167.6467...	203.757	31.41608475	169.4809...	202.9000

Building Two 20% No Shading

Date	Outside Temperature	1E1 Heat Generation (Oil)	1E1 Chiller (Electricity)	1E1 Total (Energy)	1E2 Heat Generation (Oil)	1E2 Chiller (Electricity)	1E2 Total (Energy)	1E3 Heat Generation (Oil)	1E3 Chiller (Electricity)	1E3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.67938	0.00119581	13.6800	9.687198	0.00339055	9.69059	8.887407	0.00463844	8.892120
2/1/2002	8.615029	9.674738	0.0291796	9.70394	6.611216	0.06461011	6.67583	5.980433	0.08097226	6.007453
3/1/2002	9.745699	8.362716	0.2725547	8.63527	5.782329	0.439276	6.22161	5.219814	0.4984015	5.718216
4/1/2002	13.88528	2.620104	3.893323	6.51343	1.707436	4.708342	6.41578	1.534744	4.967525	6.502269
5/1/2002	19.40779	0.003450008	16.14211	16.1456	0.001818515	17.09757	17.0994	0.001610987	17.35648	17.35809
6/1/2002	20.98195	0	20.83371	20.8337	0	21.05867	21.0587	0	21.87497	21.87497
7/1/2002	22.73441	0	36.48504	36.4850	0	36.80112	36.8011	0	36.92507	36.92507
8/1/2002	23.04382	0	34.87878	34.8788	0	35.18038	35.1803	0	35.28463	35.28463
9/1/2002	21.49319	0	27.84379	27.8438	0	28.04935	28.0494	0	28.85194	28.85194
10/1/2002	19.88199	0.005169457	19.2933	19.2985	0.001514312	20.06748	20.069	0.001328125	20.99435	20.99588
11/1/2002	14.60778	0.530221	3.862818	4.39904	0.2327091	5.241461	5.47417	0.196327	5.037527	5.835854
12/1/2002	9.495833	10.90519	0.3414151	11.3060	7.814097	0.6181874	8.43228	7.229578	0.7148526	7.944431
		45.84008847	163.877816	209.725	31.83831403	171.120793	202.968	29.05935211	173.191598	202.2509

Building Two 20% No Shading

		2C1			2C2			2C3		
Date	Outside Temperature	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
7/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
8/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
9/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
10/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Building Two 20% No Shading

		2E1			2E2			2E3		
Date	Outside Temperature	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
7/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
8/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
9/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
10/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Building Two 20% With Shading

		1C1			1C2			1C3		
Date	Outside Temperature	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)	Heat Generation (Oil)	Chiller (Electricity)	Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]
2/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
8/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
9/1/2002	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]
10/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12/1/2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Building Two 20% With Shading

Date	Outside Temperature	1E1 Heat Generation (Oil)	1E1 Chiller (Electricity)	1E1 Total (Energy)	1E2 Heat Generation (Oil)	1E2 Chiller (Electricity)	1E2 Total (Energy)	1E3 Heat Generation (Oil)	1E3 Chiller (Electricity)	1E3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.60083	0	16.60083	14.62592	0	14.62592	13.8029	0	13.8029
2/1/2002	8.615029	14.24776	0.0008857	14.24865	11.10564	0.0008029	11.1065	10.4402	0.0051629	10.46418
3/1/2002	9.725829	12.98022	0.0295291	13.01018	10.38583	0.0654218	10.45225	9.81771	0.0079812	9.825804
4/1/2002	13.88528	4.768558	1.6198	6.387458	3.678029	1.967171	5.64577	3.44513	2.08077	5.52591
5/1/2002	19.40721	0.0166036	10.18687	10.20358	0.0072645	10.70767	10.71485	0.0061663	10.8148	10.82106
6/1/2002	20.98125	2.41471E-05	14.77804	14.77806	7.3327E-06	15.27442	15.27443	4.01868E-06	15.42256	15.42256
7/1/2002	22.71441	0	28.86403	28.86403	0	28.78925	28.78925	0	28.80651	28.80651
8/1/2002	21.84382	0	27.68032	27.68032	0	27.58924	27.58924	0	27.56724	27.56724
9/1/2002	21.47319	0	20.86052	20.86052	0	21.29801	21.29801	0	21.42	21.42
10/1/2002	15.88579	0.0122871	13.49161	13.50389	0.0034722	14.48867	14.49214	0.0029857	14.72155	14.72453
11/1/2002	14.60748	1.298181	1.510765	2.808945	0.62852	2.072182	2.700701	0.571182	2.224576	2.795602
12/1/2002	9.745813	14.57148	0.05103	14.62251	11.1726	0.119353	11.29185	10.54084	0.148572	10.68941
		66.499483	118.99278	185.49188	51.664848	122.29875	173.9676	48.649094	123.41445	172.1108

Building Two 20% With Shading

Date	Outside Temperature	2C1 Heat Generation (Oil)	2C1 Chiller (Electricity)	2C1 Total (Energy)	2C2 Heat Generation (Oil)	2C2 Chiller (Electricity)	2C2 Total (Energy)	2C3 Heat Generation (Oil)	2C3 Chiller (Electricity)	2C3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	18.18404	0	18.18404	14.25083	0	14.25083	13.46441	0	13.46441
2/1/2002	8.615029	13.91245	0.0009584	13.91414	10.81412	0.0041785	10.8183	10.19631	0.0052445	10.20984
3/1/2002	9.745815	12.8026	0.0286028	12.79118	10.13843	0.0618875	10.20012	9.57402	0.0785908	9.655025
4/1/2002	13.88528	4.612857	1.600151	6.213008	3.580771	1.920555	5.500126	3.154821	2.095811	5.4084
5/1/2002	19.40725	0.0155318	10.10216	10.10891	0.0072856	10.56451	10.57185	0.0065571	10.72258	10.72958
6/1/2002	20.58195	2.2573E-05	14.61455	14.61452	1.5583E-05	15.05926	15.05928	1.2512E-05	15.156	15.15601
7/1/2002	22.70441	0	28.62036	28.62036	0	28.47956	28.47956	0	28.52712	28.52712
8/1/2002	21.01882	0	27.41054	27.41054	0	27.27528	27.27528	0	27.31229	27.31229
9/1/2002	21.49015	0	20.71107	20.71107	0	21.10114	21.10114	0	21.2201	21.2201
10/1/2002	19.88195	0.0108472	13.44052	13.45136	0.0031402	14.36845	14.37161	0.0027014	14.62749	14.63022
11/1/2002	14.80728	1.221224	1.530771	2.752001	0.628608	2.072207	2.700678	0.519551	2.265275	2.784714
12/1/2002	9.455811	14.20122	0.0531081	14.25442	10.85718	0.1247118	10.98217	10.2271	0.155611	10.38271
		64.825117	118.10847	182.94846	50.267413	121.10041	171.3683	47.367808	122.13849	169.50675

Building Two 20% With Shading

Date	Outside Temperature	2E1 Heat Generation (Oil)	2E1 Chiller (Electricity)	2E1 Total (Energy)	2E2 Heat Generation (Oil)	2E2 Chiller (Electricity)	2E2 Total (Energy)	2E3 Heat Generation (Oil)	2E3 Chiller (Electricity)	2E3 Total (Energy)
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.46441	0	13.46441	13.57452	0	13.57452	12.77285	0	12.77285
2/1/2002	8.615029	10.19631	0.0052445	10.20984	10.26522	0.0062158	10.27455	9.83086	0.0022608	9.84021
3/1/2002	9.745815	9.57402	0.0785908	9.655025	9.54865	0.0782275	9.720886	9.07172	0.0919812	9.167054
4/1/2002	13.88528	3.354025	2.095811	5.4084	3.35168	2.00171	5.36175	3.12976	2.15082	5.28615
5/1/2002	19.40725	0.0065571	10.72258	10.72958	0.0065675	10.79172	10.79818	0.0058565	10.91143	10.91728
6/1/2002	20.58195	1.2619E-05	15.156	15.15601	1.2081E-05	15.21542	15.21542	8.7809E-06	15.35779	15.35779
7/1/2002	22.70441	0	28.52712	28.52712	0	28.62408	28.62408	0	28.86078	28.86078
8/1/2002	21.01882	0	27.31229	27.31229	0	27.44006	27.44006	0	27.45791	27.45791
9/1/2002	21.49015	0	21.2201	21.2201	0	21.32611	21.32611	0	21.44925	21.44925
10/1/2002	19.88195	0.0027014	14.62749	14.63022	0.0025558	14.67158	14.67415	0.0022129	14.92151	14.92381
11/1/2002	14.80728	0.519551	2.265275	2.784714	0.515763	2.241507	2.757265	0.456721	2.44085	2.89772
12/1/2002	9.455811	10.2271	0.155611	10.38271	10.2811	0.15347	10.43457	9.642	0.158255	9.80026
		47.367808	122.13849	169.50675	47.662184	122.55448	170.22715	44.718609	123.67493	168.39492

Building Two		40 1C1None			40 1C2None			40 1C3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	14.16301	0.0026105	14.16562	10.59047	0.005076	10.59555	9.902579	0.006156	9.908735
2/1/2002	8.615029	9.788377	0.0480883	9.836465	7.060772	0.082629	7.143401	6.538214	0.096312	6.634526
3/1/2002	9.745699	8.47205	0.3969981	8.869048	6.231435	0.562856	6.794291	5.765219	0.614614	6.379833
4/1/2002	13.88528	2.69134	4.48278	7.17412	1.890837	5.213982	7.104819	1.743294	5.432259	7.175553
5/1/2002	19.40779	0.00363964	17.45288	17.45652	0.00173463	18.38354	18.38527	0.00152214	18.62466	18.62618
6/1/2002	20.98195	0	22.06276	22.06276	0	22.87295	22.87295	0	23.07631	23.07631
7/1/2002	22.73441	0	38.43882	38.43882	0	38.83044	38.83044	0	38.96476	38.96476
8/1/2002	23.04382	0	36.85217	36.85217	0	37.2406	37.2406	0	37.35788	37.35788
9/1/2002	21.49319	0	29.83413	29.83413	0	30.68907	30.68907	0	30.89498	30.89498
10/1/2002	19.88199	0.00725273	20.74102	20.74827	0.00194745	22.06366	22.06561	0.0015535	22.36509	22.36664
11/1/2002	14.60778	0.6052638	4.458858	5.064122	0.2938402	5.687726	5.981566	0.2545325	6.018589	6.273122
12/1/2002	9.495833	11.5855	0.4080592	11.99356	8.722543	0.643566	9.366109	8.215144	0.717051	8.932195
		47.3164332	**175.17917**	**222.4956**	**34.7935793**	**182.2761**	**217.0697**	**32.4220581**	**184.1687**	**216.5907**

Building Two		40 1E1None			40 1E2None			40 1E3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.76919	0.0063397	12.77553	9.030293	0.014962	9.045255	8.290401	0.018935	8.309336
2/1/2002	8.615029	8.707181	0.0743498	8.781531	5.839192	0.136716	5.975908	5.274866	0.160856	5.435722
3/1/2002	9.745699	7.508445	0.5012918	8.009737	5.080615	0.740341	5.820956	4.572888	0.818186	5.391074
4/1/2002	13.88528	2.337467	4.897653	7.23512	1.509883	5.845691	7.355574	1.35942	6.128386	7.487806
5/1/2002	19.40779	0.0024176	18.033	18.03542	0.0012855	19.10583	19.10712	0.00114165	19.38196	19.3831
6/1/2002	20.98195	0	22.59339	22.59339	0	23.51599	23.51599	0	23.74508	23.74508
7/1/2002	22.73441	0	38.84346	38.84346	0	39.3237	39.3237	0	39.47852	39.47852
8/1/2002	23.04382	0	37.23933	37.23933	0	37.70269	37.70269	0	37.83825	37.83825
9/1/2002	21.49319	0	30.35469	30.35469	0	31.32218	31.32218	0	31.5564	31.5564
10/1/2002	19.88199	0.00474287	21.39018	21.39492	0.00123161	22.89212	22.89335	0.00107122	23.23331	23.23438
11/1/2002	14.60778	0.4835589	5.038604	5.522163	0.2069522	6.574958	6.78191	0.1774571	6.987063	7.16452
12/1/2002	9.495833	10.4517	0.5443793	10.99608	7.469462	0.878483	8.347945	6.929623	0.987201	7.916824
		42.2647024	**179.51667**	**221.7814**	**29.1389143**	**188.0537**	**217.1926**	**26.606868**	**190.3341**	**216.941**

Building Two		40 2C1None			40 2C2None			40 2C3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.56889	0.0065	12.57539	8.867498	0.013269	8.880767	8.153953	0.016556	8.170509
2/1/2002	8.615029	8.567833	0.066626	8.634459	5.76905	0.121917	5.890967	5.224207	0.144152	5.368359
3/1/2002	9.745699	7.389608	0.458787	7.848395	5.052336	0.675602	5.727938	4.566559	0.747385	5.313944
4/1/2002	13.88528	2.291723	4.666461	6.958184	1.495392	5.530557	7.025949	1.351542	5.791449	7.142991
5/1/2002	19.40779	0.0027458	17.49527	17.49802	0.00153	18.46336	18.46489	0.001418	18.71564	18.71706
6/1/2002	20.98195	0	21.99959	21.99959	0	22.82544	22.82544	0	23.03423	23.03423
7/1/2002	22.73441	0	38.0541	38.0541	0	38.42406	38.42406	0	38.55561	38.55561
8/1/2002	23.04382	0	36.51007	36.51007	0	36.87587	36.87587	0	36.99059	36.99059
9/1/2002	21.49319	0	29.72907	29.72907	0	30.59368	30.59368	0	30.80706	30.80706
10/1/2002	19.88199	0.00432521	20.91191	20.91624	0.001325	22.3087	22.31003	0.001165	22.62841	22.62957
11/1/2002	14.60778	0.4629965	4.85427	5.317267	0.202816	6.306064	6.50888	0.175289	6.695722	6.871011
12/1/2002	9.495833	10.21144	0.511381	10.72282	7.303032	0.826013	8.129045	6.777558	0.927864	7.705422
		41.4995615	**175.264**	**216.7636**	**28.69298**	**182.9645**	**211.6575**	**26.25169**	**185.0547**	**211.3064**

Building Two		40 2E1None			40 2E2None			40 2E3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	11.98006	0.008909	11.98897	8.229989	0.019077	8.249066	7.498144	0.023916	7.52206
2/1/2002	8.615029	8.146555	0.076432	8.222987	5.316566	0.143543	5.460109	4.762831	0.170585	4.933416
3/1/2002	9.745699	7.040145	0.482537	7.522682	4.663013	0.725444	5.388457	4.172803	0.8066	4.979403
4/1/2002	13.88528	2.160697	4.735906	6.896603	1.367833	5.664083	7.031916	1.22574	5.9444	7.17014
5/1/2002	19.40779	0.00256646	17.50239	17.50496	0.001559	18.49497	18.49653	0.001405	18.75495	18.75635
6/1/2002	20.98195	0	21.96907	21.96907	0	22.80753	22.80753	0	23.02013	23.02013
7/1/2002	22.73441	0	37.87366	37.87366	0	38.24273	38.24273	0	38.37534	38.37534
8/1/2002	23.04382	0	36.31032	36.31032	0	36.67114	36.67114	0	36.78593	36.78593
9/1/2002	21.49319	0	29.60478	29.60478	0	30.47772	30.47772	0	30.69195	30.69195
10/1/2002	19.88199	0.0035261	20.95863	20.96216	0.001189	22.39196	22.39315	0.001032	22.71938	22.72041
11/1/2002	14.60778	0.4135548	5.015146	5.428701	0.177688	6.568246	6.745934	0.155183	6.985752	7.140935
12/1/2002	9.495833	9.717387	0.559003	10.27639	6.786526	0.915086	7.701612	6.255361	1.031373	7.286734
		39.4644914	**175.0968**	**214.5613**	**26.54436**	**183.1215**	**209.6659**	**24.0725**	**185.3103**	**209.3828**

Building Two		40 1C1Shading			40 1C2Shading			40 1C3Shading		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.34051	0	17.34051	16.59064	0	16.59064	15.9032	0	15.9032
2/1/2002	8.615029	13.04352	0.003258	13.04678	12.5901	0.001082	12.59118	12.04637	0.001532	12.0479
3/1/2002	9.745699	11.95227	0.047369	11.99964	11.75092	0.043656	11.79458	11.27624	0.05269	11.32893
4/1/2002	13.88528	4.30314	1.787675	6.090815	4.333844	1.764961	6.098805	4.137333	1.852487	5.98982
5/1/2002	19.40779	0.01147854	10.54916	10.56064	0.01175905	10.34123	10.35299	0.00975277	10.47802	10.48777
6/1/2002	20.98195	1.2383E-05	14.99198	14.99199	1.7798E-05	14.87564	14.87566	1.4757E-05	15.00158	15.00159
7/1/2002	22.73441	0	29.08175	29.08175	0	28.63295	28.63295	0	28.67506	28.67506
8/1/2002	23.04382	0	28.01107	28.01107	0	27.59466	27.59466	0	27.6259	27.6259
9/1/2002	21.49319	0	21.66411	21.66411	0	21.38553	21.38553	0	21.50797	21.50797
10/1/2002	19.88199	0.00886697	14.28982	14.29869	0.00663185	14.25895	14.26558	0.0053049	14.4724	14.4777
11/1/2002	14.60778	1.043835	1.789769	2.833604	0.9638547	1.752239	2.716094	0.8619068	1.865156	2.727063
12/1/2002	9.495833	13.50096	0.077071	13.57803	12.9367	0.062529	12.99923	12.37308	0.077747	12.45083
		61.2045929	**122.293**	**183.4976**	**59.1844674**	**120.7134**	**179.8979**	**56.6132022**	**121.6105**	**178.2237**

Building Two		40 1E1Shading			40 1E2Shading			40 1E3Shading		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.78291	0	16.78291	14.85406	0	14.85406	14.11802	0	14.11802
2/1/2002	8.615029	12.58347	0.003485	12.58695	11.09766	0.004724	11.10238	10.51377	0.0068	10.52057
3/1/2002	9.745699	11.50927	0.061263	11.57053	10.38586	0.07748	10.46334	9.855078	0.092288	9.947366
4/1/2002	13.88528	4.148674	1.968971	6.117645	3.685763	2.075858	5.761621	3.46452	2.19356	5.65808
5/1/2002	19.40779	0.00791572	10.94949	10.95741	0.00647806	11.02525	11.03173	0.00572546	11.1968	11.20253
6/1/2002	20.98195	2.2773E-06	15.51213	15.51213	0	15.54298	15.54298	0	15.69133	15.69133
7/1/2002	22.73441	0	29.5463	29.5463	0	29.24247	29.24247	0	29.30127	29.30127
8/1/2002	23.04382	0	28.37609	28.37609	0	28.13692	28.13692	0	28.18107	28.18107
9/1/2002	21.49319	0	22.08082	22.08082	0	22.1344	22.1344	0	22.28086	22.28086
10/1/2002	19.88199	0.00756641	14.70123	14.7088	0.00345943	15.1284	15.13186	0.00288286	15.38317	15.38605
11/1/2002	14.60778	0.9704973	1.912942	2.883439	0.6718326	2.172229	2.844062	0.5779239	2.344627	2.922551
12/1/2002	9.495833	13.10004	0.088174	13.18821	11.39698	0.117237	11.51422	10.8014	0.143971	10.94537
		59.1103457	**125.2009**	**184.3112**	**52.1020931**	**125.6579**	**177.76**	**49.3393202**	**126.8157**	**176.1551**

		40 2C1Shading			40 2C2Shading			40 2C3Shading		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.34051	0	17.34051	14.41547	0	14.41547	13.69209	0	13.69209
2/1/2002	8.615029	13.04352	0.003258	13.04678	10.75275	0.005036	10.75779	10.17991	0.007041	10.18695
3/1/2002	9.745699	11.95227	0.047369	11.99964	10.09505	0.074041	10.16909	9.581498	0.088137	9.669635
4/1/2002	13.88528	4.30314	1.787675	6.090815	3.561872	2.022894	5.584766	3.359599	2.133686	5.493285
5/1/2002	19.40779	0.01147854	10.54916	10.56064	0.00680124	10.82215	10.82895	0.0060825	10.97988	10.98596
6/1/2002	20.98195	1.2383E-05	14.99198	14.99199	9.3276E-06	15.25172	15.25173	6.1743E-06	15.38836	15.38837
7/1/2002	22.73441	0	29.08175	29.08175	0	28.84811	28.84811	0	28.89231	28.89231
8/1/2002	23.04382	0	28.01107	28.01107	0	27.82353	27.82353	0	27.85533	27.85533
9/1/2002	21.49319	0	21.66411	21.66411	0	21.90662	21.90662	0	22.03897	22.03897
10/1/2002	19.88199	0.00886697	14.28982	14.29869	0.00322582	14.99032	14.99355	0.00274229	15.23078	15.23352
11/1/2002	14.60778	1.043835	1.789769	2.833604	0.6239848	2.189522	2.813507	0.5392156	2.357267	2.896483
12/1/2002	9.495833	13.50096	0.077071	13.57803	11.02143	0.123297	11.14473	10.4375	0.150379	10.58788
		61.2045929	**122.293**	**183.4976**	**50.4805932**	**124.0572**	**174.5378**	**47.7986436**	**125.1221**	**172.9208**

		40 2E1Shading			40 2E2Shading			40 2E3Shading		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.34051	0	17.34051	13.56035	0	13.56035	12.81588	1.24E-06	12.81588
2/1/2002	8.615029	13.04352	0.003258	13.04678	10.0556	0.008547	10.06415	9.466621	0.01152	9.478141
3/1/2002	9.745699	11.95227	0.047369	11.99964	9.46252	0.090359	9.552879	8.93008	0.10735	9.03743
4/1/2002	13.88528	4.30314	1.787675	6.090815	3.274075	2.155757	5.429832	3.061095	2.280732	5.341827
5/1/2002	19.40779	0.01147854	10.54916	10.56064	0.00601421	11.08209	11.0881	0.00531315	11.25092	11.25623
6/1/2002	20.98195	1.2383E-05	14.99198	14.99199	4.8594E-06	15.46556	15.46556	0	15.6062	15.6062
7/1/2002	22.73441	0	29.08175	29.08175	0	29.02633	29.02633	0	29.07434	29.07434
8/1/2002	23.04382	0	28.01107	28.01107	0	27.97516	27.97516	0	28.00967	28.00967
9/1/2002	21.49319	0	21.66411	21.66411	0	22.15153	22.15153	0	22.28929	22.28929
10/1/2002	19.88199	0.00886697	14.28982	14.29869	0.00260288	15.32398	15.32658	0.00229329	15.57672	15.57901
11/1/2002	14.60778	1.043835	1.789769	2.833604	0.5164269	2.421348	2.937775	0.4425361	2.620353	3.062889
12/1/2002	9.495833	13.50096	0.077071	13.57803	10.29227	0.161709	10.45398	9.697958	0.196452	9.89441
		61.2045929	**122.293**	**183.4976**	**47.1698638**	**125.8624**	**173.0322**	**44.4217765**	**127.0235**	**171.4453**

Building Two 100% No Shading

		100 1C1			100 1C2			100 1C3		
Date/Time	Outside Temp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.40685	0.069028	13.47588	10.34874	0.085658	10.4344	9.797237	0.08997	9.887207
2/1/2002	8.615029	8.751463	0.178567	8.93003	6.450039	0.230115	6.680154	6.02949	0.244122	6.273612
3/1/2002	9.745699	7.640064	0.910248	8.550312	5.746357	1.097802	6.844159	5.374203	1.149809	6.524012
4/1/2002	13.88528	2.491994	6.205195	8.697189	1.824001	6.937039	8.76104	1.708625	7.13372	8.842345
5/1/2002	19.40779	0.002513	20.57097	20.57348	0.001111	21.51883	21.51994	0.00096	21.73853	21.73949
6/1/2002	20.98195	0	24.87909	24.87909	0	25.68639	25.68639	0	25.86976	25.86976
7/1/2002	22.73441	0	42.4178	42.4178	0	42.91572	42.91572	0	43.05228	43.05228
8/1/2002	23.04382	0	40.85753	40.85753	0	41.37622	41.37622	0	41.50463	41.50463
9/1/2002	21.49319	0	34.06527	34.06527	0	35.01279	35.01279	0	35.22375	35.22375
10/1/2002	19.88199	0.005946	24.20062	24.20657	0.00143	25.5273	25.52873	0.001171	25.80805	25.80922
11/1/2002	14.60778	0.556238	6.311642	6.86788	0.280012	7.520383	7.800395	0.245697	7.81592	8.061617
12/1/2002	9.495833	11.28675	0.741833	12.02858	8.803476	0.974535	9.778011	8.394699	1.038033	9.432732
		44.14182	**201.4078**	**245.5496**	**33.45517**	**208.8828**	**242.3379**	**31.55208**	**210.6686**	**242.2207**

Building Two 100% No Shading

		100 2C1			100 2C2			100 2C3		
Date/Time	Outside Temp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	11.11142	0.155218	11.26664	7.949657	0.199279	8.148936	7.369276	0.210628	7.579904
2/1/2002	8.615029	7.169412	0.334622	7.504034	4.858847	0.449328	5.308175	4.427001	0.481886	4.908887
3/1/2002	9.745699	6.139567	1.199398	7.338965	4.166007	1.491018	5.657025	3.782765	1.574706	5.357471
4/1/2002	13.88528	1.928282	6.790456	8.718738	1.27319	7.733049	9.006239	1.161726	7.98634	9.148066
5/1/2002	19.40779	0.001811	20.96013	20.96194	1.00E-03	21.99112	21.99212	8.75E-04	22.23036	22.23124
6/1/2002	20.98195	0	25.10717	25.10717	0	25.97311	25.97311	0	26.1683	26.1683
7/1/2002	22.73441	0	42.22068	42.22068	0	42.73774	42.73774	0	42.87986	42.87986
8/1/2002	23.04382	0	40.67033	40.67033	0	41.20364	41.20364	0	41.33712	41.33712
9/1/2002	21.49319	0	34.22827	34.22827	0	35.2409	35.2409	0	35.46135	35.46135
10/1/2002	19.88199	3.23E-03	24.71762	24.72085	9.95E-04	26.16981	26.1708	8.72E-04	26.47586	26.47673
11/1/2002	14.60778	0.383683	7.198318	7.582001	0.175341	8.699408	8.874749	0.154223	9.058505	9.212728
12/1/2002	9.495833	9.270053	1.033028	10.30308	6.778423	1.384821	8.163244	6.358604	1.483816	7.84242
		36.00745	**204.6152**	**240.6227**	**25.20346**	**213.2732**	**238.4767**	**23.25534**	**215.3487**	**238.6041**

Building Two 100% No Shading

		100 1E1			100 1E2			100 1E3		
Date/Time	Outside Temp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	11.22596	0.204006	11.42997	7.991892	0.265706	8.257598	7.382304	0.280949	7.663253
2/1/2002	8.615029	7.257692	0.429672	7.687364	4.85461	0.580132	5.434742	4.403062	0.623115	5.026177
3/1/2002	9.745699	6.165332	1.381955	7.547287	4.086285	1.735415	5.8217	3.683643	1.837372	5.521015
4/1/2002	13.88528	1.94702	7.366899	9.313919	1.259899	8.452152	9.712051	1.143878	8.738013	9.881891
5/1/2002	19.40779	1.37E-03	21.99994	22.00131	6.35E-04	23.18308	23.18371	5.27E-04	23.45141	23.45194
6/1/2002	20.98195	0	26.18743	26.18743	0	27.1903	27.1903	0	27.41125	27.41125
7/1/2002	22.73441	0	43.59067	43.59067	0	44.2677	44.2677	0	44.43836	44.43836
8/1/2002	23.04382	0	41.92099	41.92099	0	42.59403	42.59403	0	42.75219	42.75219
9/1/2002	21.49319	0	35.36719	35.36719	0	36.52708	36.52708	0	36.77672	36.77672
10/1/2002	19.88199	3.32E-03	25.67983	25.68315	8.75E-04	27.29268	27.29356	7.51E-04	27.6302	27.63095
11/1/2002	14.60778	0.392567	7.7171	8.109667	0.172501	9.365596	9.538097	0.150846	9.755968	9.906814
12/1/2002	9.495833	9.435157	1.166966	10.60212	6.853149	1.56793	8.421079	6.410451	1.679964	8.090415
		36.42842	**213.0126**	**249.4411**	**25.21985**	**223.0218**	**248.2416**	**23.17546**	**225.3755**	**248.551**

Building Two 100% No Shading

		100 2E1			100 2E2			100 2E3		
Date/Time	Outside Temp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	10.26688	0.206236	10.47312	7.102159	0.27155	7.373709	6.509781	0.288372	6.798153
2/1/2002	8.615029	6.657752	0.435654	7.093406	4.336471	0.596575	4.933046	3.904193	0.642593	4.546786
3/1/2002	9.745699	5.673757	1.350305	7.024062	3.679861	1.709236	5.389097	3.299751	1.81203	5.111781
4/1/2002	13.88528	1.752612	7.050393	8.803005	1.110441	8.102113	9.212554	1.003405	8.38008	9.383485
5/1/2002	19.40779	1.68E-03	21.11927	21.12095	9.31E-04	22.19938	22.20031	8.10E-04	22.44857	22.44938
6/1/2002	20.98195	0	25.22156	25.22156	0	26.11432	26.11432	0	26.31608	26.31608
7/1/2002	22.73441	0	42.14301	42.14301	0	42.68216	42.68216	0	42.82924	42.82924
8/1/2002	23.04382	0	40.56507	40.56507	0	41.09937	41.09937	0	41.2351	41.2351
9/1/2002	21.49319	0	34.20084	34.20084	0	35.24374	35.24374	0	35.47329	35.47329
10/1/2002	19.88199	2.58E-03	24.88608	24.88866	8.63E-04	26.4041	26.40496	7.46E-04	26.72375	26.7245
11/1/2002	14.60778	0.331866	7.575987	7.907853	0.150303	9.217032	9.367335	0.133822	9.604682	9.738504
12/1/2002	9.495833	8.559066	1.182869	9.741935	6.050978	1.604244	7.655222	5.62357	1.722468	7.346038
		33.2462	**205.9373**	**239.1835**	**22.43201**	**215.2438**	**237.6758**	**20.47608**	**217.4763**	**237.9523**

Building Two 100% With Shading

		100 1C1			100 1C2			100 1C3		
Date/Time	Outside Temp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	20.65918	0	20.65918	17.45856	0	17.45856	16.89413	0	16.89413
2/1/2002	8.615029	15.38266	0.000476	15.38314	12.86983	0.000952	12.87078	12.42268	0.001244	12.42392
3/1/2002	9.745699	13.90611	0.052872	13.95898	11.95819	0.077095	12.03529	11.57959	0.085484	11.66507
4/1/2002	13.88528	5.27305	1.902726	7.175776	4.432128	2.140952	6.57308	4.274763	2.217064	6.491827
5/1/2002	19.40779	0.029904	10.94136	10.97126	0.016456	11.3735	11.38996	0.014559	11.49921	11.51377
6/1/2002	20.98195	1.96E-05	15.4536	15.45362	3.38E-06	15.85362	15.85362	1.87E-07	15.96304	15.96304
7/1/2002	22.73441	0	30.38714	30.38714	0	30.40506	30.40506	0	30.45274	30.45274
8/1/2002	23.04382	0	29.50971	29.50971	0	29.57966	29.57966	0	29.62778	29.62778
9/1/2002	21.49319	0	23.07248	23.07248	0	23.5724	23.5724	0	23.70369	23.70369
10/1/2002	19.88199	0.020746	14.82665	14.8474	0.007278	15.6846	15.69188	0.005966	15.88108	15.88705
11/1/2002	14.60778	1.575026	1.594058	3.169084	1.048968	1.948004	2.996972	0.963537	2.044971	3.008508
12/1/2002	9.495833	16.64465	0.036759	16.68141	13.88486	0.063511	13.94837	13.41854	0.074449	13.49299
		73.49135	**127.7778**	**201.2692**	**61.67627**	**130.6994**	**192.3756**	**59.57377**	**131.5508**	**191.1245**

Building Two 100% With Shading

		100 2C1			100 2C2			100 2C3		
Date/Time	Outside Temp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.54991	0	17.54991	14.27486	0	14.27486	13.68173	0	13.68173
2/1/2002	8.615029	12.74988	0.005656	12.75554	10.16974	8.74E-03	10.17848	9.701429	1.05E-02	9.711881
3/1/2002	9.745699	11.61789	0.104856	11.72275	9.527441	0.150386	9.677827	9.111193	0.165404	9.276597
4/1/2002	13.88528	4.177093	2.29371	6.470803	3.306282	2.636398	5.94268	3.139339	2.741617	5.880956
5/1/2002	19.40779	0.010798	11.77236	11.78316	5.86E-03	12.30448	12.31034	5.20E-03	12.45128	12.45648
6/1/2002	20.98195	0	16.18279	16.18279	0	16.63851	16.63851	0	16.76109	16.76109
7/1/2002	22.73441	0	30.94133	30.94133	0	30.97335	30.97335	0	31.02888	31.02888
8/1/2002	23.04382	0	30.04745	30.04745	0	30.13469	30.13469	0	30.18693	30.18693
9/1/2002	21.49319	0	23.99525	23.99525	0	24.567	24.567	0	24.71124	24.71124
10/1/2002	19.88199	0.009381	15.94512	15.9545	2.78E-03	16.95394	16.95672	2.37E-03	17.18337	17.18574
11/1/2002	14.60778	1.068251	2.241408	3.309659	0.586815	2.819775	3.40659	0.516585	2.980496	3.497081
12/1/2002	9.495833	13.86827	0.099975	13.96824	11.07102	0.166349	11.23737	10.59931	0.189495	10.78881
		61.05147	**133.6299**	**194.6814**	**48.94479**	**137.3536**	**186.2984**	**46.75716**	**138.4103**	**185.1674**

Building Two 100% With Shading

		100 1E1			100 1E2			100 1E3		
Date/Time	Outside Temp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	18.15431	0	18.15431	14.77555	0	14.77555	14.16682	0	14.16682
2/1/2002	8.615029	13.22854	4.74E-03	13.23328	10.5493	7.99E-03	10.55729	10.06186	9.93E-03	10.07179
3/1/2002	9.745699	12.01618	0.106627	12.12281	9.828289	0.156827	9.985116	9.383936	0.172925	9.556861
4/1/2002	13.88528	4.344587	2.3562	6.700787	3.415586	2.741808	6.157394	3.233336	2.857254	6.09059
5/1/2002	19.40779	1.12E-02	12.01355	12.02472	5.12E-03	12.62768	12.6328	4.47E-03	12.79377	12.79824
6/1/2002	20.98195	0	16.52751	16.52751	0	17.06213	17.06213	0	17.2011	17.2011
7/1/2002	22.73441	0	31.38196	31.38196	0	31.49567	31.49567	0	31.5682	31.5682
8/1/2002	23.04382	0	30.40806	30.40806	0	30.56307	30.56307	0	30.62931	30.62931
9/1/2002	21.49319	0	24.244	24.244	0	24.89522	24.89522	0	25.05614	25.05614
10/1/2002	19.88199	1.07E-02	16.1047	16.11542	2.83E-03	17.20738	17.21021	2.37E-03	17.45476	17.45713
11/1/2002	14.60778	1.151207	2.240875	3.392082	0.626047	2.845609	3.471656	0.547982	3.018655	3.566637
12/1/2002	9.495833	14.42722	0.098056	14.52528	11.52991	0.165806	11.69572	11.03438	0.18924	11.22362
		63.34393	**135.4863**	**198.8302**	**50.73264**	**139.7692**	**190.5018**	**48.43515**	**140.9513**	**189.3864**

Building Two 100% With Shading										
		100 2E1			100 2E2			100 2E3		
Date/Time	Outside Temp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.37302	6.07E-05	16.37308	13.03571	0.000112	13.03582	12.42221	0.000156	12.42237
2/1/2002	8.615029	11.81091	0.010656	11.82157	9.181759	0.016268	9.198027	8.695762	0.019296	8.715058
3/1/2002	9.745699	10.80794	0.134316	10.94226	8.636971	0.193601	8.830572	8.198289	0.211949	8.410238
4/1/2002	13.88528	3.79558	2.465977	6.261557	2.910487	2.866848	5.777335	2.739056	2.988632	5.727688
5/1/2002	19.40779	0.008179	12.10119	12.10937	0.004879	12.68236	12.68724	0.004276	12.84348	12.84776
6/1/2002	20.98195	0	16.45859	16.45859	0	16.93921	16.93921	0	17.06826	17.06826
7/1/2002	22.73441	0	31.12041	31.12041	0	31.16553	31.16553	0	31.22469	31.22469
8/1/2002	23.04382	0	30.19766	30.19766	0	30.295	30.295	0	30.34996	30.34996
9/1/2002	21.49319	0	24.26135	24.26135	0	24.86464	24.86464	0	25.01432	25.01432
10/1/2002	19.88199	0.006789	16.34225	16.34904	0.00226	17.42177	17.42403	0.001974	17.66577	17.66774
11/1/2002	14.60778	0.909497	2.555436	3.464933	0.462328	3.258727	3.721055	0.404891	3.458325	3.863216
12/1/2002	9.495833	12.87876	0.144328	13.02309	10.0544	0.238006	10.29241	9.565318	0.270454	9.835772
		56.59068	**135.7922**	**192.3829**	**44.28879**	**139.9421**	**184.2309**	**42.03178**	**141.1153**	**183.1471**

Table 73: Building Three North-West- Extended Results (monthly Data)

Building Three Base Case

Date/Time	System Misc	Heat Generation (Oil)	Chiller (Electricity)	Outside Temperature
	kWh/m2	kWh/m2	kWh/m2	°C
1/1/2002	2.304703	17.36271	0	8.013307
2/1/2002	2.551635	12.62677	1.65E-02	8.615029
3/1/2002	2.469324	10.82896	0.197032	9.745699
4/1/2002	2.551635	3.703422	3.263696	13.88528
5/1/2002	2.469324	2.53E-02	14.20131	19.40779
6/1/2002	2.551635	5.09E-03	19.08096	20.98195
7/1/2002	2.551635	3.41E-06	34.33224	22.73441
8/1/2002	2.469324	0	32.31251	23.04382
9/1/2002	2.551635	8.66E-04	24.98935	21.49319
10/1/2002	2.469324	2.53E-02	16.48069	19.88199
11/1/2002	2.551635	1.089123	2.126759	14.60778
12/1/2002	2.551635	13.9137	9.83E-02	9.495833
	30.043444	**59.58127946**	**147.0993812**	

Building Three 20% No Shading

Date/Time	OutsideTemp	1C1None			1C2None			1C3None		
		Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	18.47288	0	18.47288	15.02681	0	15.02681	14.3806	5.17E-06	14.38061
2/1/2002	8.615029	13.79459	0.0027542	13.79734	11.12512	0.009487	11.13461	10.62188	0.012978	10.63486
3/1/2002	9.745699	12.09366	0.0827517	12.17641	9.932937	0.137579	10.07052	9.489429	0.157045	9.646474
4/1/2002	13.88528	4.294771	2.347238	6.642009	3.40521	2.716303	6.121513	3.238799	2.832765	6.071564
5/1/2002	19.40779	0.034395	12.32971	12.36411	0.027556	12.8906	12.91816	0.026213	13.04636	13.07257
6/1/2002	20.98195	0.005533	16.92921	16.93474	0.004371	17.46698	17.47135	0.004059	17.60714	17.6112
7/1/2002	22.73441	0	31.76948	31.76948	0	31.82344	31.82344	0	31.8798	31.8798
8/1/2002	23.04382	0	30.17188	30.17188	0	30.17651	30.17651	0	30.20336	30.20336
9/1/2002	21.49319	0.001244	23.29733	23.29857	0.001086	23.6618	23.66289	0.00107	23.7494	23.75047
10/1/2002	19.88199	0.034495	15.37492	15.40942	0.024048	16.20089	16.22494	0.022431	16.37988	16.40231
11/1/2002	14.60778	1.238027	1.912503	3.15053	0.807688	2.491454	3.299142	0.748787	2.663086	3.411873
12/1/2002	9.495833	14.82459	0.0779685	14.90256	11.88507	0.159401	12.04447	11.36367	0.188766	11.55244
		64.79419	**134.29575**	**199.0899**	**52.2399**	**137.7344**	**189.9743**	**49.89694**	**138.7206**	**188.6175**

Building Three 20% No Shading

Date/Time	OutsideTemp	1E1None			1E2None			1E3None		
		Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.78301	0	16.78301	13.15486	6.32E-06	13.15487	12.45758	1.26E-05	12.45759
2/1/2002	8.615029	12.35537	0.0055312	12.3609	9.518272	0.017333	9.535605	8.967829	0.02264	8.990469
3/1/2002	9.745699	10.89731	0.1121602	11.00947	8.526326	0.19156	8.717886	8.02129	0.22007	8.24136
4/1/2002	13.88528	3.733726	2.612241	6.345967	2.784969	3.116704	5.901673	2.601051	3.275295	5.876346
5/1/2002	19.40779	0.022797	12.98881	13.01161	0.018285	13.70523	13.72352	0.017667	13.89798	13.91565
6/1/2002	20.98195	0.003877	17.60062	17.6045	0.003057	18.26073	18.26379	0.002936	18.43107	18.43401
7/1/2002	22.73441	0	32.37333	32.37333	0	32.51485	32.51485	0	32.5987	32.5987
8/1/2002	23.04382	0	30.76926	30.76926	0	30.84487	30.84487	0	30.88842	30.88842
9/1/2002	21.49319	0.00045	24.02979	24.03024	0.00034	24.50731	24.50765	0.00033	24.62045	24.62078
10/1/2002	19.88199	0.021746	16.17142	16.19317	0.013491	17.18282	17.19631	0.012211	17.40087	17.41308
11/1/2002	14.60778	0.952274	2.237573	3.189847	0.534265	3.037602	3.571867	0.482007	3.275985	3.757992
12/1/2002	9.495833	13.3136	0.1180892	13.43169	10.23532	0.238948	10.47427	9.686563	0.284735	9.971298
		58.08416	**139.01882**	**197.103**	**44.78918**	**143.618**	**188.4071**	**42.24946**	**144.9162**	**187.1657**

Building Three 20% No Shading										
		2C1None			2C2None			2C3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.33368	0	16.33368	12.83315	0	12.83315	12.14797	1E-05	12.14798
2/1/2002	8.615029	12.04215	0.004932	12.04708	9.295879	0.016165	9.312044	8.766685	0.021376	8.788061
3/1/2002	9.745699	10.61182	0.102143	10.71396	8.33663	0.175231	8.511861	7.859577	0.201072	8.060649
4/1/2002	13.88528	3.618408	2.506383	6.124791	2.713845	2.956104	5.669949	2.544373	3.099934	5.644307
5/1/2002	19.40779	0.021931	12.6175	12.63943	0.018576	13.23777	13.25635	0.018003	13.40855	13.42655
6/1/2002	20.98195	0.004195	17.14991	17.15411	0.003405	17.71448	17.71788	0.00324	17.86237	17.86561
7/1/2002	22.73441	0	31.75886	31.75886	0	31.80217	31.80217	0	31.85817	31.85817
8/1/2002	23.04382	0	30.21267	30.21267	0	30.19995	30.19995	0	30.22452	30.22452
9/1/2002	21.49319	0.000474	23.59482	23.59529	0.000398	23.98026	23.98066	0.000393	24.07364	24.07403
10/1/2002	19.88199	0.019854	15.87603	15.89588	0.012444	16.79174	16.80418	0.011869	16.98798	16.99985
11/1/2002	14.60778	0.885013	2.192339	3.077352	0.499034	2.94347	3.442504	0.452453	3.165535	3.617988
12/1/2002	9.495833	12.92139	0.115059	13.03645	9.925154	0.231151	10.15631	9.393813	0.274348	9.668161
		56.45891	**136.1306**	**192.5896**	**43.63851**	**140.0485**	**183.687**	**41.19838**	**141.1775**	**182.3759**

Building Three 20% No Shading										
		2E1None			2E2None			2E3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	15.51377	0	15.51377	11.9507	9.55E-06	11.95071	11.24795	4.23E-05	11.24799
2/1/2002	8.615029	11.40856	0.00646	11.41502	8.613112	0.020078	8.63319	8.065657	0.02636	8.092017
3/1/2002	9.745699	10.08503	0.111903	10.19693	7.740217	0.193917	7.934134	7.244835	0.223528	7.468363
4/1/2002	13.88528	3.379107	2.578803	5.95791	2.460782	3.074974	5.535756	2.286281	3.233466	5.519747
5/1/2002	19.40779	0.019913	12.75109	12.771	0.016854	13.40238	13.41923	0.016255	13.5821	13.59835
6/1/2002	20.98195	0.003946	17.24206	17.24601	0.003375	17.82626	17.82963	0.003219	17.9793	17.98252
7/1/2002	22.73441	0	31.75498	31.75498	0	31.79494	31.79494	0	31.85259	31.85259
8/1/2002	23.04382	0	30.22393	30.22393	0	30.21108	30.21108	0	30.23841	30.23841
9/1/2002	21.49319	0.000315	23.72222	23.72254	0.000294	24.12549	24.12578	0.000299	24.22286	24.22316
10/1/2002	19.88199	0.015429	16.11165	16.12708	0.010602	17.07208	17.08268	0.010287	17.28076	17.29105
11/1/2002	14.60778	0.753146	2.34848	3.101626	0.390901	3.199081	3.589982	0.351232	3.449743	3.800975
12/1/2002	9.495833	12.2174	0.136788	12.35419	9.193199	0.275755	9.468954	8.652711	0.328957	8.981668
		53.39662	**136.9884**	**190.385**	**40.38004**	**141.196**	**181.5761**	**37.87873**	**142.4181**	**180.2968**

Building Three 20% with Shading										
		1C1Shad			1C2Shad			1C3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	18.42687	0	18.42687	14.96887	0	14.96887	14.32061	5.06E-06	14.32062
2/1/2002	8.615029	13.95566	0.00164	13.9573	11.27379	0.005984	11.27977	10.76963	0.008501	10.77813
3/1/2002	9.745699	12.36184	0.06789	12.42973	10.20998	0.113213	10.32319	9.767725	0.129834	9.897559
4/1/2002	13.88528	4.503412	2.097714	6.601126	3.622583	2.410928	6.033511	3.455613	2.514085	5.969698
5/1/2002	19.40779	0.039924	11.54132	11.58124	0.03057	11.99583	12.0264	0.029036	12.13219	12.16123
6/1/2002	20.98195	0.005909	15.89787	15.90378	0.004986	16.32108	16.32607	0.004731	16.44141	16.44614
7/1/2002	22.73441	2.58E-07	30.5206	30.5206	5.57E-07	30.44295	30.44295	6.46E-07	30.47555	30.47555
8/1/2002	23.04382	0	29.12443	29.12443	0	29.02148	29.02148	0	29.02934	29.02934
9/1/2002	21.49319	0.001331	22.48198	22.48331	0.001182	22.7586	22.75978	0.001168	22.83238	22.83355
10/1/2002	19.88199	0.037171	14.94634	14.98351	0.025235	15.70889	15.73413	0.023532	15.87767	15.9012
11/1/2002	14.60778	1.245976	1.90969	3.155666	0.822007	2.481937	3.303944	0.762137	2.650716	3.412853
12/1/2002	9.495833	14.78001	0.08381	14.86382	11.84878	0.168625	12.0174	11.32906	0.199248	11.52831
		65.3581	**128.6733**	**194.0314**	**52.80798**	**131.4295**	**184.2375**	**50.46324**	**132.2909**	**182.7542**

Building Three 20% with Shading

		1E1Shad			1E2Shad			1E3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.71087	0	16.71087	13.07184	6.23E-06	13.07185	12.37341	1.22E-05	12.37342
2/1/2002	8.615029	12.4643	0.003573	12.46787	9.619959	0.012696	9.632655	9.06979	0.017506	9.087296
3/1/2002	9.745699	11.10171	0.095091	11.1968	8.751761	0.164404	8.916165	8.25066	0.189235	8.439895
4/1/2002	13.88528	3.913017	2.372175	6.285192	2.971255	2.814847	5.786102	2.784702	2.957219	5.741921
5/1/2002	19.40779	0.02529	12.25757	12.28286	0.019147	12.87545	12.8946	0.018421	13.05067	13.06909
6/1/2002	20.98195	0.004164	16.66072	16.66488	0.003371	17.21161	17.21498	0.003189	17.36159	17.36478
7/1/2002	22.73441	0	31.2431	31.2431	0	31.26442	31.26442	0	31.3211	31.3211
8/1/2002	23.04382	0	29.81668	29.81668	0	29.7898	29.7898	0	29.81588	29.81588
9/1/2002	21.49319	0.00051	23.28965	23.29016	0.000406	23.68622	23.68663	0.000396	23.78667	23.78707
10/1/2002	19.88199	0.023286	15.78599	15.80928	0.014112	16.74183	16.75594	0.012773	16.952	16.96477
11/1/2002	14.60778	0.95882	2.24638	3.2052	0.543228	3.037261	3.580489	0.489609	3.271984	3.761593
12/1/2002	9.495833	13.26013	0.125593	13.38572	10.19048	0.251156	10.44164	9.6442	0.29783	9.94203
		58.4621	**133.8965**	**192.3586**	**45.18556**	**137.8497**	**183.0353**	**42.64715**	**139.0217**	**181.6688**

Building Three 20% with Shading

		2C1Shad			2C2Shad			2C3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.26515	0	16.26515	12.75235	0	12.75235	12.065	9.81E-06	12.06501
2/1/2002	8.615029	12.13413	0.003265	12.13739	9.377107	0.012008	9.389115	8.846913	0.016574	8.863487
3/1/2002	9.745699	10.78872	0.086542	10.87526	8.52337	0.151126	8.674496	8.048488	0.174114	8.222602
4/1/2002	13.88528	3.777668	2.292536	6.070204	2.877928	2.691529	5.569457	2.706844	2.821466	5.52831
5/1/2002	19.40779	0.024024	11.95854	11.98256	0.019179	12.49274	12.51192	0.018739	12.64918	12.66792
6/1/2002	20.98195	0.004463	16.30019	16.30465	0.003698	16.76995	16.77365	0.003538	16.90209	16.90563
7/1/2002	22.73441	0	30.74246	30.74246	0	30.67609	30.67609	0	30.71496	30.71496
8/1/2002	23.04382	0	29.3572	29.3572	0	29.25932	29.25932	0	29.26855	29.26855
9/1/2002	21.49319	0.00053	22.93441	22.93494	0.000462	23.25179	23.25225	0.000459	23.33483	23.33529
10/1/2002	19.88199	0.021182	15.54418	15.56536	0.013221	16.41209	16.42531	0.012301	16.60251	16.61481
11/1/2002	14.60778	0.889257	2.20833	3.097587	0.505421	2.956649	3.46207	0.458096	3.177324	3.63542
12/1/2002	9.495833	12.87201	0.122832	12.99484	9.882635	0.243528	10.12616	9.35254	0.287931	9.640471
		56.77713	**131.5505**	**188.3276**	**43.95537**	**134.9168**	**178.8722**	**41.51292**	**135.9495**	**177.4625**

Building Three 20% with Shading

		2E1Shad			2E2Shad			2E3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	15.43733	0	15.43733	11.86284	9.26E-06	11.86285	11.15773	4.15E-05	11.15777
2/1/2002	8.615029	11.46916	0.004564	11.47372	8.665351	0.01599	8.681341	8.116313	0.021561	8.137874
3/1/2002	9.745699	10.21403	0.096931	10.31096	7.880391	0.170612	8.051003	7.387164	0.197902	7.585066
4/1/2002	13.88528	3.517771	2.384745	5.902516	2.600962	2.831815	5.432777	2.423955	2.976774	5.400729
5/1/2002	19.40779	0.020868	12.15749	12.17836	0.017323	12.73302	12.75034	0.016788	12.90036	12.91715
6/1/2002	20.98195	0.004193	16.48003	16.48422	0.003572	16.97697	16.98054	0.003508	17.11635	17.11986
7/1/2002	22.73441	0	30.84232	30.84232	0	30.78604	30.78604	0	30.82759	30.82759
8/1/2002	23.04382	0	29.45921	29.45921	0	29.37427	29.37427	0	29.38592	29.38592
9/1/2002	21.49319	0.000357	23.13118	23.13154	0.000343	23.47275	23.47309	0.000349	23.56149	23.56184
10/1/2002	19.88199	0.016495	15.82366	15.84015	0.010789	16.74085	16.75164	0.010466	16.94327	16.95374
11/1/2002	14.60778	0.754962	2.373408	3.12837	0.39416	3.221893	3.616053	0.353535	3.47091	3.824445
12/1/2002	9.495833	12.16601	0.145493	12.3115	9.147651	0.290137	9.437788	8.608266	0.344245	8.952511
		53.60118	**132.899**	**186.5002**	**40.58338**	**136.6144**	**177.1977**	**38.07807**	**137.7464**	**175.8245**

Building Three 40% No Shading										
		1C1None			1C2None			1C3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	19.23332	0	19.23332	15.99777	0	15.99777	15.41269	4.96E-06	15.41269
2/1/2002	8.615029	14.17441	0.0061401	14.18055	11.68362	0.013108	11.69673	11.23178	0.016103	11.24788
3/1/2002	9.745699	12.17576	0.1140852	12.28985	10.16616	0.171481	10.33764	9.772421	0.190805	9.963226
4/1/2002	13.88528	4.301531	2.694557	6.996088	3.459764	3.074885	6.534649	3.308337	3.189104	6.497441
5/1/2002	19.40779	0.032221	13.27795	13.31017	0.02571	13.89438	13.92009	0.024551	14.05352	14.07807
6/1/2002	20.98195	0.005124	18.16724	18.17236	0.003853	18.78996	18.79381	0.003667	18.94185	18.94552
7/1/2002	22.73441	0	33.34076	33.34076	0	33.53939	33.53939	0	33.61732	33.61732
8/1/2002	23.04382	0	31.42598	31.42598	0	31.55516	31.55516	0	31.6023	31.6023
9/1/2002	21.49319	0.001156	24.19899	24.20015	0.000987	24.62724	24.62823	0.000969	24.72129	24.72226
10/1/2002	19.88199	0.034561	15.8073	15.84186	0.023952	16.61646	16.64041	0.022366	16.78462	16.80699
11/1/2002	14.60778	1.371905	1.890774	3.262679	0.920854	2.392812	3.313666	0.857843	2.534551	3.392394
12/1/2002	9.495833	15.56227	0.0651648	15.62743	12.78202	0.124041	12.90606	12.30686	0.14592	12.45278
		66.89226	**140.98894**	**207.8812**	**55.06469**	**144.7989**	**199.8636**	**52.94148**	**145.7974**	**198.7389**

Building Three 40% No Shading										
		1E1None			1E2None			1E3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.20949	0	17.20949	13.76147	6.34E-06	13.76148	13.11895	1.26E-05	13.11896
2/1/2002	8.615029	12.4653	0.0109867	12.47629	9.775878	0.023891	9.799769	9.268936	0.029363	9.298299
3/1/2002	9.745699	10.7521	0.1556834	10.90778	8.481947	0.246428	8.728375	8.013454	0.276781	8.290235
4/1/2002	13.88528	3.640472	3.039733	6.680205	2.729949	3.590891	6.32084	2.562908	3.754472	6.31738
5/1/2002	19.40779	0.021185	14.06024	14.08143	0.017282	14.86211	14.87939	0.016597	15.06313	15.07973
6/1/2002	20.98195	0.003465	18.95264	18.95611	0.002727	19.72679	19.72952	0.00254	19.9104	19.91294
7/1/2002	22.73441	0	34.02075	34.02075	0	34.3362	34.3362	0	34.44261	34.44261
8/1/2002	23.04382	0	32.10388	32.10388	0	32.32321	32.32321	0	32.39121	32.39121
9/1/2002	21.49319	0.00038	25.06139	25.06177	0.000271	25.62819	25.62846	0.000252	25.75294	25.75319
10/1/2002	19.88199	0.021026	16.75738	16.77841	0.013247	17.78722	17.80047	0.012047	18.00117	18.01322
11/1/2002	14.60778	1.007699	2.280426	3.288125	0.568563	3.020786	3.589349	0.514451	3.230935	3.745386
12/1/2002	9.495833	13.73998	0.1093925	13.84937	10.79093	0.213374	11.0043	10.28053	0.252447	10.53298
		58.8611	**146.5525**	**205.4136**	**46.14226**	**151.7591**	**197.9014**	**43.79066**	**153.1055**	**196.8961**

Building Three 40% No Shading										
		2C1None			2C2None			2C3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.75216	0	16.75216	13.45558	0	13.45558	12.82906	9.68E-06	12.82907
2/1/2002	8.615029	12.16216	0.009601	12.17176	9.583505	0.021331	9.604836	9.101844	0.026346	9.12819
3/1/2002	9.745699	10.49371	0.138728	10.63244	8.345967	0.218044	8.564011	7.91012	0.243994	8.154114
4/1/2002	13.88528	3.544224	2.86179	6.406014	2.682809	3.337495	6.020304	2.528553	3.481608	6.010161
5/1/2002	19.40779	0.021064	13.51613	13.53719	0.017965	14.19873	14.21669	0.017274	14.3742	14.39147
6/1/2002	20.98195	0.003729	18.31055	18.31428	0.003057	18.96792	18.97098	0.002887	19.12773	19.13062
7/1/2002	22.73441	0	33.1749	33.1749	0	33.36243	33.36243	0	33.4418	33.4418
8/1/2002	23.04382	0	31.32606	31.32606	0	31.43405	31.43405	0	31.47909	31.47909
9/1/2002	21.49319	0.000407	24.42894	24.42935	0.00032	24.88109	24.88141	0.000318	24.98146	24.98178
10/1/2002	19.88199	0.019153	16.29971	16.31886	0.012113	17.20797	17.22008	0.011569	17.39529	17.40686
11/1/2002	14.60778	0.944763	2.189599	3.134362	0.538937	2.855722	3.394659	0.490053	3.044338	3.534391
12/1/2002	9.495833	13.32912	0.101846	13.43097	10.47383	0.197989	10.67182	9.983251	0.23322	10.21647
		57.27049	**142.3579**	**199.6283**	**45.11408**	**146.6828**	**191.7969**	**42.87493**	**147.8291**	**190.704**

Building Three 40% No Shading

		2E1None			2E2None			2E3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	15.80259	0	15.80259	12.434	9.4E-06	12.43401	11.78836	4.29E-05	11.7884
2/1/2002	8.615029	11.43557	0.01192	11.44749	8.797897	0.026962	8.824859	8.296227	0.033468	8.329695
3/1/2002	9.745699	9.906452	0.149589	10.05604	7.674324	0.239771	7.914095	7.216194	0.271074	7.487268
4/1/2002	13.88528	3.283844	2.933774	6.217618	2.407926	3.463874	5.8718	2.249872	3.624285	5.874157
5/1/2002	19.40779	0.018951	13.60528	13.62423	0.016152	14.32264	14.33879	0.015624	14.50828	14.5239
6/1/2002	20.98195	0.003589	18.34478	18.34837	0.003029	19.02391	19.02694	0.002865	19.18903	19.19189
7/1/2002	22.73441	0	33.07527	33.07527	0	33.26491	33.26491	0	33.34629	33.34629
8/1/2002	23.04382	0	31.25341	31.25341	0	31.359	31.359	0	31.40413	31.40413
9/1/2002	21.49319	0.000264	24.51017	24.51043	0.000235	24.98119	24.98143	0.00024	25.08581	25.08605
10/1/2002	19.88199	0.014696	16.52454	16.53924	0.010349	17.48516	17.49551	0.009608	17.68538	17.69499
11/1/2002	14.60778	0.78938	2.35482	3.1442	0.413402	3.125724	3.539126	0.373681	3.343904	3.717585
12/1/2002	9.495833	12.49586	0.126492	12.62235	9.604074	0.247175	9.851249	9.101794	0.292002	9.393796
		53.7512	**142.89**	**196.6412**	**41.36139**	**147.5403**	**188.9017**	**39.05446**	**148.7837**	**187.8382**

Building Three 40% with Shading

		1C1Shad			1C2Shad			1C3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	19.96252	0	19.96252	16.70637	0	16.70637	16.12073	4.62E-06	16.12073
2/1/2002	8.615029	15.10154	0.001468	15.10301	12.58415	0.004691	12.58884	12.1292	0.006284	12.13548
3/1/2002	9.745699	13.34081	0.056502	13.39731	11.34988	0.090876	11.44076	10.95275	0.10369	11.05644
4/1/2002	13.88528	4.994217	1.989351	6.983568	4.159797	2.2435	6.403297	4.007079	2.327185	6.334264
5/1/2002	19.40779	0.046556	11.21581	11.26237	0.032566	11.61629	11.64886	0.030489	11.73499	11.76548
6/1/2002	20.98195	0.00588	15.67427	15.68015	0.00493	16.08021	16.08514	0.004743	16.19345	16.19819
7/1/2002	22.73441	0	30.27311	30.27311	0	30.21339	30.21339	0	30.24703	30.24703
8/1/2002	23.04382	0	28.81649	28.81649	0	28.72685	28.72685	0	28.73744	28.73744
9/1/2002	21.49319	0.001317	22.02936	22.03068	0.001173	22.27007	22.27124	0.00116	22.3325	22.33366
10/1/2002	19.88199	0.042282	14.36504	14.40732	0.02755	15.01418	15.04173	0.025507	15.15433	15.17984
11/1/2002	14.60778	1.550915	1.653196	3.204111	1.089356	2.070456	3.159812	1.022559	2.189205	3.211764
12/1/2002	9.495833	16.07172	0.049052	16.12077	13.27533	0.095341	13.37067	12.79698	0.113031	12.91001
		71.11776	**126.1236**	**197.2414**	**59.2311**	**128.4259**	**187.657**	**57.0912**	**129.1391**	**186.2303**

Building Three 40% with Shading

		1E1Shad			1E2Shad			1E3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.84901	0	17.84901	14.3952	6E-06	14.39521	13.7567	1.15E-05	13.75671
2/1/2002	8.615029	13.27713	0.003328	13.28046	10.57574	0.010203	10.58594	10.07393	0.013664	10.08759
3/1/2002	9.745699	11.8065	0.085236	11.89174	9.594005	0.145218	9.739223	9.138583	0.166838	9.305421
4/1/2002	13.88528	4.256511	2.297365	6.553876	3.344566	2.690625	6.035191	3.167729	2.81536	5.983089
5/1/2002	19.40779	0.026299	12.03486	12.06116	0.019058	12.61683	12.63589	0.018344	12.77825	12.79659
6/1/2002	20.98195	0.004062	16.56473	16.56879	0.003276	17.11618	17.11946	0.003163	17.26202	17.26518
7/1/2002	22.73441	0	31.11039	31.11039	0	31.16541	31.16541	0	31.22538	31.22538
8/1/2002	23.04382	0	29.60995	29.60995	0	29.60805	29.60805	0	29.63674	29.63674
9/1/2002	21.49319	0.000489	22.98648	22.98697	0.000388	23.3647	23.36509	0.000378	23.45647	23.45685
10/1/2002	19.88199	0.024788	15.33686	15.36165	0.01441	16.21146	16.22587	0.013014	16.39947	16.41248
11/1/2002	14.60778	1.155952	1.987033	3.142985	0.686153	2.603334	3.289487	0.620378	2.780401	3.400779
12/1/2002	9.495833	14.17656	0.084334	14.26089	11.21695	0.169231	11.38618	10.70727	0.201736	10.90901
		62.5773	**132.1006**	**194.6779**	**49.84975**	**135.7012**	**185.551**	**47.49949**	**136.7363**	**184.2358**

Building Three 40% with Shading

		2C1Shad			2C2Shad			2C3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.32125	0	17.32125	14.01984	0	14.01984	13.39441	9.08E-06	13.39442
2/1/2002	8.615029	12.88377	0.003012	12.88678	10.28323	0.009466	10.2927	9.802265	0.012806	9.815071
3/1/2002	9.745699	11.43252	0.076394	11.50891	9.315244	0.13029	9.445534	8.88593	0.149744	9.035674
4/1/2002	13.88528	4.084506	2.21027	6.294776	3.221663	2.556727	5.77839	3.061607	2.667744	5.729351
5/1/2002	19.40779	0.024688	11.71657	11.74126	0.01924	12.20942	12.22866	0.018541	12.35047	12.36901
6/1/2002	20.98195	0.004363	16.18309	16.18745	0.003618	16.64721	16.65083	0.003458	16.77385	16.77731
7/1/2002	22.73441	0	30.57948	30.57948	0	30.53856	30.53856	0	30.57845	30.57845
8/1/2002	23.04382	0	29.11369	29.11369	0	29.03168	29.03168	0	29.04556	29.04556
9/1/2002	21.49319	0.000515	22.59095	22.59147	0.000449	22.88184	22.88229	0.000447	22.95519	22.95564
10/1/2002	19.88199	0.022291	15.05436	15.07665	0.013478	15.83198	15.84546	0.012527	15.99778	16.01031
11/1/2002	14.60778	1.069333	1.941401	3.010734	0.638573	2.51072	3.149293	0.580608	2.672399	3.253007
12/1/2002	9.495833	13.71492	0.080086	13.79501	10.84793	0.159854	11.00778	10.35729	0.190316	10.54761
		60.55816	**129.5493**	**190.1075**	**48.36326**	**132.5077**	**180.871**	**46.11708**	**133.3943**	**179.5114**

Building Three 40% with Shading

		2E1Shad			2E2Shad			2E3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.3068	0	16.3068	12.93533	8.42E-06	12.93534	12.29119	3.94E-05	12.29123
2/1/2002	8.615029	12.07704	0.004379	12.08142	9.425659	0.01359	9.439249	8.925632	0.018053	8.943685
3/1/2002	9.745699	10.75413	0.087116	10.84125	8.557701	0.151349	8.70905	8.108569	0.17414	8.282709
4/1/2002	13.88528	3.763355	2.309362	6.072717	2.874533	2.707884	5.582417	2.706604	2.834411	5.541015
5/1/2002	19.40779	0.020965	11.93048	11.95144	0.017251	12.47038	12.48763	0.01672	12.62399	12.64071
6/1/2002	20.98195	0.004102	16.37305	16.37715	0.003484	16.86751	16.87099	0.003419	17.00193	17.00535
7/1/2002	22.73441	0	30.68349	30.68349	0	30.65211	30.65211	0	30.69599	30.69599
8/1/2002	23.04382	0	29.21212	29.21212	0	29.13831	29.13831	0	29.15876	29.15876
9/1/2002	21.49319	0.000345	22.81225	22.8126	0.000333	23.13091	23.13124	0.00034	23.2102	23.21054
10/1/2002	19.88199	0.016887	15.36467	15.38156	0.01083	16.20193	16.21276	0.010513	16.38123	16.39174
11/1/2002	14.60778	0.886726	2.104309	2.991035	0.479255	2.767865	3.24712	0.42981	2.958153	3.387963
12/1/2002	9.495833	12.83298	0.102492	12.93547	9.930665	0.20575	10.13641	9.426843	0.244836	9.671679
		56.66333	**130.9837**	**187.647**	**44.23504**	**134.3076**	**178.5426**	**41.91964**	**135.3017**	**177.2214**

Building Three 100% NoShading

		1C1None			1C2None			1C3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	19.90879	0	19.90879	17.19093	2.65E-06	17.19093	16.74989	4.91E-06	16.74989
2/1/2002	8.615029	14.13904	0.027771	14.16681	12.08386	0.036183	12.12004	11.75086	0.038786	11.78965
3/1/2002	9.745699	11.68326	0.316373	11.99963	10.0508	0.384102	10.4349	9.764471	0.403238	10.16771
4/1/2002	13.88528	4.043917	4.112481	8.156398	3.357205	4.502645	7.85985	3.247906	4.600809	7.848715
5/1/2002	19.40779	0.027293	16.51099	16.53828	0.022058	17.1713	17.19336	0.021075	17.31103	17.3321
6/1/2002	20.98195	0.003832	21.91373	21.91756	0.002827	22.60073	22.60356	0.002657	22.73851	22.74117
7/1/2002	22.73441	0	38.15311	38.15311	0	38.52559	38.52559	0	38.6127	38.6127
8/1/2002	23.04382	0	35.51577	35.51577	0	35.80342	35.80342	0	35.86095	35.86095
9/1/2002	21.49319	0.000924	27.29157	27.29249	0.00075	27.75823	27.75898	0.000721	27.83707	27.83779
10/1/2002	19.88199	0.035565	17.69293	17.72849	0.024929	18.4081	18.43303	0.023425	18.53328	18.55671
11/1/2002	14.60778	1.490049	2.173502	3.663551	1.116701	2.591776	3.708477	1.071524	2.695072	3.766596
12/1/2002	9.495833	16.37656	0.085579	16.46214	14.03729	0.132377	14.16967	13.67769	0.147852	13.82554
		67.70923	**163.7938**	**231.503**	**57.88735**	**167.9145**	**225.8018**	**56.31022**	**168.7793**	**225.0895**

Building Three 100% NoShading										
		1E1None			1E2None			1E3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.69112	0	16.69112	13.79758	6.26E-06	13.79759	13.30375	1.59E-05	13.30377
2/1/2002	8.615029	11.51367	0.056004	11.56967	9.239466	0.078419	9.317885	8.853118	0.085443	8.938561
3/1/2002	9.745699	9.418386	0.487434	9.90582	7.482181	0.626401	8.108582	7.124123	0.662755	7.786878
4/1/2002	13.88528	3.066226	5.02128	8.087506	2.327552	5.696836	8.024388	2.210045	5.86057	8.070615
5/1/2002	19.40779	0.017719	18.17653	18.19425	0.014723	19.12347	19.13819	0.014226	19.31634	19.33057
6/1/2002	20.98195	0.002426	23.59468	23.59711	0.001671	24.54023	24.5419	0.001495	24.72239	24.72389
7/1/2002	22.73441	0	39.74056	39.74056	0	40.33265	40.33265	0	40.4613	40.4613
8/1/2002	23.04382	0	36.96093	36.96093	0	37.4471	37.4471	0	37.53753	37.53753
9/1/2002	21.49319	0.000214	28.9834	28.98361	0.000123	29.67399	29.67411	0.000112	29.79544	29.79555
10/1/2002	19.88199	0.018248	19.45925	19.4775	0.011527	20.47491	20.48644	0.01097	20.65122	20.66219
11/1/2002	14.60778	0.923734	2.972151	3.895885	0.563497	3.695537	4.259034	0.524384	3.86895	4.393334
12/1/2002	9.495833	13.59036	0.187683	13.77804	11.07596	0.293298	11.36926	10.68747	0.326771	11.01424
		55.2421	**175.6399**	**230.882**	**44.51428**	**181.9828**	**226.4971**	**42.72969**	**183.2887**	**226.0184**

Building Three 100% NoShading										
		2C1None			2C2None			2C3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.33511	0	16.33511	13.5846	0	13.5846	13.11463	9.75E-06	13.11464
2/1/2002	8.615029	11.29703	0.043937	11.34097	9.177886	0.060928	9.238814	8.822806	0.06636	8.889166
3/1/2002	9.745699	9.270435	0.412423	9.682858	7.498271	0.52082	8.019091	7.175593	0.550263	7.725856
4/1/2002	13.88528	3.008455	4.567629	7.576084	2.322154	5.115495	7.437649	2.214638	5.251829	7.466467
5/1/2002	19.40779	0.018284	17.16796	17.18624	0.015608	17.94549	17.9611	0.0151	18.11088	18.12598
6/1/2002	20.98195	0.002899	22.47541	22.47831	0.002237	23.25413	23.25637	0.00207	23.40811	23.41018
7/1/2002	22.73441	0	38.32349	38.32349	0	38.7384	38.7384	0	38.83548	38.83548
8/1/2002	23.04382	0	35.67419	35.67419	0	35.98818	35.98818	0	36.05273	36.05273
9/1/2002	21.49319	0.000235	27.86753	27.86777	0.000174	28.39773	28.3979	0.000168	28.48823	28.4884
10/1/2002	19.88199	0.016951	18.57166	18.58861	0.01144	19.42017	19.43161	0.010996	19.56715	19.57815
11/1/2002	14.60778	0.881901	2.705465	3.587366	0.549384	3.314388	3.863772	0.514018	3.460633	3.974651
12/1/2002	9.495833	13.20044	0.157205	13.35764	10.80604	0.243779	11.04982	10.43971	0.27157	10.71128
		54.03174	**167.9669**	**221.9986**	**43.96779**	**172.9995**	**216.9673**	**42.30973**	**174.0632**	**216.373**

Building Three 100% NoShading										
		2E1None			2E2None			2E3None		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	14.97501	8.71E-06	14.97502	12.14724	5.78E-05	12.1473	11.65766	0.000108	11.65777
2/1/2002	8.615029	10.26414	0.056697	10.32084	8.080382	0.080902	8.161284	7.703759	0.08862	7.792379
3/1/2002	9.745699	8.411258	0.461143	8.872401	6.539709	0.596278	7.135987	6.198189	0.632983	6.831172
4/1/2002	13.88528	2.669553	4.781821	7.451374	1.980513	5.427796	7.408309	1.872332	5.587058	7.45939
5/1/2002	19.40779	0.016541	17.41466	17.4312	0.014124	18.24977	18.26389	0.013634	18.42477	18.4384
6/1/2002	20.98195	0.002736	22.64343	22.64617	0.002103	23.4665	23.4686	0.001941	23.62906	23.631
7/1/2002	22.73441	0	38.28306	38.28306	0	38.72986	38.72986	0	38.833	38.833
8/1/2002	23.04382	0	35.67057	35.67057	0	36.0032	36.0032	0	36.0696	36.0696
9/1/2002	21.49319	0.000145	28.08762	28.08776	0.000115	28.65604	28.65615	0.000109	28.75313	28.75324
10/1/2002	19.88199	0.012953	18.98627	18.99922	0.009099	19.9066	19.9157	0.008809	20.06643	20.07524
11/1/2002	14.60778	0.684586	3.040488	3.725074	0.386665	3.775408	4.162073	0.359214	3.950476	4.30969
12/1/2002	9.495833	12.01575	0.211527	12.22728	9.587518	0.330284	9.917802	9.210566	0.367185	9.577751
		49.05267	**169.6373**	**218.69**	**38.74747**	**175.2227**	**213.9702**	**37.02621**	**176.4024**	**213.4286**

Building Three 100% with Shading										
		1C1Shad			1C2Shad			1C3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	22.04158	0	22.04158	19.20984	0	19.20984	18.7661	4E-06	18.7661
2/1/2002	8.615029	16.41602	0.001849	16.41787	14.31646	0.004723	14.32118	13.97561	0.006098	13.98171
3/1/2002	9.745699	14.066	0.076027	14.14203	12.45168	0.106563	12.55824	12.16131	0.117257	12.27857
4/1/2002	13.88528	5.240476	2.370034	7.61051	4.558549	2.5849	7.143449	4.449526	2.649886	7.099412
5/1/2002	19.40779	0.049065	12.43221	12.48127	0.037285	12.81061	12.84789	0.035507	12.90769	12.9432
6/1/2002	20.98195	0.005353	17.36108	17.36643	0.004473	17.77703	17.7815	0.004282	17.8756	17.87988
7/1/2002	22.73441	0	32.57728	32.57728	0	32.63476	32.63476	0	32.67588	32.67588
8/1/2002	23.04382	0	30.59181	30.59181	0	30.59499	30.59499	0	30.61194	30.61194
9/1/2002	21.49319	0.001268	22.96431	22.96558	0.001116	23.17014	23.17126	0.001102	23.21215	23.21325
10/1/2002	19.88199	0.061028	14.58171	14.64274	0.044239	15.06936	15.1136	0.04156	15.16093	15.20249
11/1/2002	14.60778	1.96712	1.556716	3.523836	1.582733	1.862743	3.445476	1.536334	1.947155	3.483489
12/1/2002	9.495833	17.89956	0.041661	17.94122	15.54123	0.073679	15.61491	15.17791	0.085532	15.26344
		77.74747	**134.5547**	**212.3022**	**67.7476**	**136.6895**	**204.4371**	**66.14924**	**137.2501**	**203.3994**

Building Three 100% with Shading										
		1E1Shad			1E2Shad			1E3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	18.62597	0	18.62597	15.66131	5.75E-06	15.66132	15.17163	1.07E-05	15.17164
2/1/2002	8.615029	13.57956	0.006602	13.58616	11.28242	0.013291	11.29571	10.90198	0.016316	10.9183
3/1/2002	9.745699	11.7054	0.137911	11.84331	9.863039	0.199722	10.06276	9.523716	0.21965	9.743366
4/1/2002	13.88528	4.114284	2.927302	7.041586	3.348561	3.31394	6.662501	3.218271	3.421818	6.640089
5/1/2002	19.40779	0.022923	13.84125	13.86417	0.017868	14.44453	14.4624	0.017259	14.58603	14.60329
6/1/2002	20.98195	0.003436	18.88381	18.88725	0.002746	19.49542	19.49817	0.002572	19.6281	19.63067
7/1/2002	22.73441	0	34.02905	34.02905	0	34.24396	34.24396	0	34.31594	34.31594
8/1/2002	23.04382	0	31.93536	31.93536	0	32.06806	32.06806	0	32.10847	32.10847
9/1/2002	21.49319	0.000456	24.54288	24.54334	0.000302	24.92181	24.92211	0.000292	24.99505	24.99534
10/1/2002	19.88199	0.027736	16.12007	16.14781	0.016529	16.87069	16.88722	0.014874	17.00878	17.02365
11/1/2002	14.60778	1.310067	2.027465	3.337532	0.901952	2.525954	3.427906	0.851454	2.656202	3.507656
12/1/2002	9.495833	14.95312	0.082451	15.03557	12.39739	0.144361	12.54175	12.00546	0.166906	12.17237
		64.34295	**144.5341**	**208.8771**	**53.49212**	**148.2417**	**201.7339**	**51.70751**	**149.1233**	**200.8308**

Building Three 100% with Shading										
		2C1Shad			2C2Shad			2C3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	17.98635	0	17.98635	15.22772	0	15.22772	14.75885	8.36E-06	14.75886
2/1/2002	8.615029	13.09183	0.005915	13.09775	10.93521	0.012045	10.94726	10.57857	0.014783	10.59335
3/1/2002	9.745699	11.23044	0.127717	11.35816	9.515197	0.18132	9.696517	9.202296	0.19851	9.400806
4/1/2002	13.88528	3.912778	2.815072	6.72785	3.204552	3.140032	6.344584	3.089931	3.233783	6.323714
5/1/2002	19.40779	0.021757	13.47511	13.49687	0.018129	13.97207	13.9902	0.017531	14.09268	14.11021
6/1/2002	20.98195	0.003711	18.45366	18.45737	0.003067	18.96174	18.96481	0.002907	19.07654	19.07945
7/1/2002	22.73441	0	33.44363	33.44363	0	33.55427	33.55427	0	33.60601	33.60601
8/1/2002	23.04382	0	31.3505	31.3505	0	31.39068	31.39068	0	31.41386	31.41386
9/1/2002	21.49319	0.000446	24.0349	24.03535	0.000369	24.31606	24.31643	0.000367	24.37007	24.37044
10/1/2002	19.88199	0.024558	15.72005	15.74461	0.015062	16.35416	16.36922	0.013947	16.46951	16.48346
11/1/2002	14.60778	1.209776	1.951651	3.161427	0.842635	2.395149	3.237784	0.800237	2.511266	3.311503
12/1/2002	9.495833	14.40035	0.074127	14.47448	11.96902	0.128666	12.09769	11.59957	0.148256	11.74783
		61.882	**141.4523**	**203.3343**	**51.73096**	**144.4062**	**196.1372**	**50.06421**	**145.1353**	**195.1995**

Building Three 100% with Shading										
		2E1Shad			2E2Shad			2E3Shad		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.50661	0	16.50661	13.6831	7.68E-06	13.68311	13.19615	3.74E-05	13.19619
2/1/2002	8.615029	11.92281	0.009848	11.93266	9.723696	0.018754	9.74245	9.351914	0.022629	9.374543
3/1/2002	9.745699	10.24091	0.155576	10.39649	8.4373	0.221548	8.658848	8.106449	0.242799	8.349248
4/1/2002	13.88528	3.454776	3.008672	6.463448	2.721426	3.402387	6.123813	2.600433	3.512516	6.112949
5/1/2002	19.40779	0.018719	13.84489	13.86361	0.016243	14.40291	14.41915	0.015748	14.53632	14.55207
6/1/2002	20.98195	0.003494	18.78505	18.78854	0.002973	19.33997	19.34294	0.002821	19.46398	19.4668
7/1/2002	22.73441	0	33.62792	33.62792	0	33.77237	33.77237	0	33.83129	33.83129
8/1/2002	23.04382	0	31.52833	31.52833	0	31.58597	31.58597	0	31.61242	31.61242
9/1/2002	21.49319	0.000284	24.40825	24.40853	0.000261	24.72712	24.72738	0.000267	24.7877	24.78797
10/1/2002	19.88199	0.016563	16.21057	16.22713	0.01069	16.91819	16.92888	0.010351	17.04773	17.05808
11/1/2002	14.60778	0.931191	2.192034	3.123225	0.574754	2.73039	3.305144	0.536548	2.869653	3.406201
12/1/2002	9.495833	13.11416	0.103057	13.21722	10.65106	0.178821	10.82988	10.26975	0.205879	10.47563
		56.20952	**143.8742**	**200.0837**	**45.8215**	**147.2984**	**193.1199**	**44.09043**	**148.133**	**192.2234**

Table 74: Building Four North-East- Extended Results (monthly Data)

Building Four Base Case

Date/Time	System Misc	Heat Generation (Oil)	Chiller (Electricity)	Outside Temperature
	kWh/m2	kWh/m2	kWh/m2	°C
1/1/2002	2.109504	13.43861	3.90E-06	8.013307
2/1/2002	2.335522	10.30706	9.26E-03	8.615029
3/1/2002	2.260183	9.719012	0.0707717	9.745699
4/1/2002	2.335522	3.605786	1.823176	13.88528
5/1/2002	2.260183	2.22E-02	9.417366	19.40779
6/1/2002	2.335522	3.09E-03	13.08167	20.98195
7/1/2002	2.335522	0	25.48439	22.73441
8/1/2002	2.260183	0	24.61653	23.04382
9/1/2002	2.335522	8.26E-05	19.33808	21.49319
10/1/2002	2.260183	9.27E-03	13.7006	19.88199
11/1/2002	2.335522	0.6994792	2.329199	14.60778
12/1/2002	2.335522	10.42504	0.1751533	9.495833
	27.49889	**48.22959505**	**110.0461973**	

Building Four 20% No Shading

		1C1			1C2			1C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.22911	3.714E-06	13.22911	10.32908	0.000197	10.32928	9.817556	0.000327	9.817883
2/1/2002	8.615029	10.1585	0.0094932	10.16799	7.894405	0.021508	7.915913	7.490387	0.026894	7.517281
3/1/2002	9.745699	9.589993	0.0735412	9.663534	7.711107	0.128117	7.839224	7.342942	0.146399	7.489341
4/1/2002	13.88528	3.549832	1.855292	5.405124	2.786445	2.164532	4.950977	2.643816	2.25862	4.902436
5/1/2002	19.40779	0.022147	9.477727	9.499874	0.015849	9.851873	9.867722	0.015466	9.970004	9.98547
6/1/2002	20.98195	0.0031129	13.13321	13.13632	0.002079	13.45629	13.45837	0.001857	13.55522	13.55708
7/1/2002	22.73441	0	25.5534	25.5534	0	25.46262	25.46262	0	25.4999	25.4999
8/1/2002	23.04382	0	24.69623	24.69623	0	24.63177	24.63177	0	24.66042	24.66042
9/1/2002	21.49319	8.18E-05	19.44155	19.44163	4.89E-05	19.77227	19.77232	4.32E-05	19.86721	19.86725
10/1/2002	19.88199	0.0090793	13.84182	13.8509	0.003997	14.63805	14.64205	0.003575	14.81333	14.81691
11/1/2002	14.60778	0.6650034	2.378411	3.043414	0.336677	3.072765	3.409442	0.298135	3.254639	3.552774
12/1/2002	9.495833	10.3004	0.1825535	10.48295	7.898594	0.32092	8.219514	7.505499	0.36502	7.870519
		47.527259	**110.64323**	**158.1705**	**36.97828**	**113.5209**	**150.4992**	**35.11928**	**114.418**	**149.5373**

Building Four 20% No Shading

		1E1			1E2			1E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.43636	1.672E-05	12.43638	9.409729	0.000354	9.410083	8.868211	0.000581	8.868792
2/1/2002	8.615029	9.447305	0.013021	9.460326	7.090371	0.030972	7.121343	6.658137	0.038705	6.696842
3/1/2002	9.745699	8.920504	0.0953345	9.015839	6.920783	0.165192	7.085975	6.521132	0.188198	6.70933
4/1/2002	13.88528	3.241572	2.018876	5.260448	2.441529	2.393819	4.835348	2.290006	2.506783	4.796789
5/1/2002	19.40779	0.0159193	9.828696	9.844615	0.01232	10.27353	10.28585	0.011707	10.40878	10.42049
6/1/2002	20.98195	0.0017128	13.4991	13.50081	0.000911	13.86771	13.86862	0.000763	13.97813	13.97889
7/1/2002	22.73441	0	25.90566	25.90566	0	25.848	25.848	0	25.89429	25.89429
8/1/2002	23.04382	0	25.01971	25.01971	0	24.98599	24.98599	0	25.02072	25.02072
9/1/2002	21.49319	4.616E-05	19.83348	19.83353	2.19E-05	20.21154	20.21156	1.54E-05	20.31692	20.31694
10/1/2002	19.88199	0.0064233	14.25012	14.25654	0.002597	15.12736	15.12996	0.002326	15.32087	15.3232
11/1/2002	14.60778	0.551163	2.608423	3.159586	0.249311	3.437443	3.686754	0.218443	3.659491	3.877934
12/1/2002	9.495833	9.604913	0.2272091	9.832122	7.14228	0.401075	7.543355	6.732024	0.457464	7.189488
		44.225918	**113.29965**	**157.5256**	**33.26985**	**116.743**	**150.0128**	**31.30277**	**117.7909**	**149.0937**

Building Four 20% No Shading

		2C1			2C2			2C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.17095	3.01E-05	12.17098	9.173547	0.000357	9.173904	8.639853	0.000597	8.64045
2/1/2002	8.615029	9.241125	0.01277	9.253895	6.918808	0.030428	6.949236	6.494526	0.038022	6.532548
3/1/2002	9.745699	8.715421	0.092446	8.807867	6.75158	0.161853	6.913433	6.362375	0.184722	6.547097
4/1/2002	13.88528	3.149684	2.000082	5.149766	2.372656	2.359724	4.73238	2.226357	2.469351	4.695708
5/1/2002	19.40779	0.014397	9.759163	9.77356	0.011006	10.17075	10.18176	0.010606	10.29873	10.30934
6/1/2002	20.98195	0.001643	13.39801	13.39965	0.000877	13.73248	13.73336	0.000756	13.83551	13.83627
7/1/2002	22.73441	0	25.75526	25.75526	0	25.66109	25.66109	0	25.6997	25.6997
8/1/2002	23.04382	0	24.86772	24.86772	0	24.80032	24.80032	0	24.82811	24.82811
9/1/2002	21.49319	3.8E-05	19.70656	19.7066	1.55E-05	20.04859	20.04861	9.34E-06	20.14658	20.14659
10/1/2002	19.88199	0.005607	14.17345	14.17906	0.002334	15.01673	15.01906	0.002091	15.20202	15.20411
11/1/2002	14.60778	0.517722	2.599713	3.117435	0.232172	3.417507	3.649679	0.203956	3.634037	3.837993
12/1/2002	9.495833	9.383484	0.228054	9.611538	6.954113	0.401456	7.355569	6.551268	0.458217	7.009485
		43.20007	**112.5933**	**155.7933**	**32.41711**	**115.8013**	**148.2184**	**30.4918**	**116.7956**	**147.2874**

Building Four 20% No Shading

		2E1			2E2			2E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	11.73863	4.69E-05	11.73868	8.712007	0.000453	8.71246	8.168334	0.000777	8.169111
2/1/2002	8.615029	8.886162	0.014678	8.90084	6.536515	0.035138	6.571653	6.10279	0.043813	6.146603
3/1/2002	9.745699	8.366031	0.102605	8.468636	6.368125	0.179537	6.547662	5.971006	0.205878	6.176884
4/1/2002	13.88528	2.984352	2.080121	5.064473	2.202542	2.467235	4.669777	2.055182	2.584095	4.639277
5/1/2002	19.40779	0.012009	9.940672	9.952681	0.009635	10.37475	10.38439	0.008902	10.50785	10.51675
6/1/2002	20.98195	0.001064	13.57718	13.57824	0.000527	13.9244	13.92493	0.000442	14.03029	14.03073
7/1/2002	22.73441	0	25.93311	25.93311	0	25.84473	25.84473	0	25.8855	25.8855
8/1/2002	23.04382	0	25.01251	25.01251	0	24.94677	24.94677	0	24.97575	24.97575
9/1/2002	21.49319	2.3E-05	19.87859	19.87861	1.55E-06	20.23133	20.23133	0	20.33195	20.33195
10/1/2002	19.88199	0.004479	14.33671	14.34119	0.001801	15.20189	15.20369	0.001592	15.39227	15.39386
11/1/2002	14.60778	0.464899	2.704026	3.168925	0.198422	3.579868	3.77829	0.174287	3.813171	3.987458
12/1/2002	9.495833	9.039395	0.249581	9.288976	6.5963	0.441049	7.037349	6.190667	0.503662	6.694329
		41.49704	**113.8298**	**155.3269**	**30.62588**	**117.2272**	**147.853**	**28.6732**	**118.275**	**146.9482**

Building Four 20% With Shading

		1C1			1C2			1C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.01342	3.75E-06	13.01342	10.11542	0.000197	10.11562	9.604339	0.000328	9.604667
2/1/2002	8.615029	9.921796	0.010345	9.932141	7.660989	0.023555	7.684544	7.256976	0.029411	7.286387
3/1/2002	9.745699	9.247253	0.08254	9.329793	7.374133	0.142517	7.51665	7.006572	0.161801	7.168373
4/1/2002	13.88528	3.377793	1.964128	5.341921	2.625191	2.290506	4.915697	2.484567	2.389525	4.874092
5/1/2002	19.40779	0.022566	9.67227	9.694836	0.015332	10.05304	10.06837	0.014542	10.17536	10.1899
6/1/2002	20.98195	0.00306	13.29111	13.29417	0.002058	13.60407	13.60613	0.001836	13.70358	13.70542
7/1/2002	22.73441	0	25.67256	25.67256	0	25.5714	25.5714	0	25.61003	25.61003
8/1/2002	23.04382	0	25.06414	25.06414	0	25.00274	25.00274	0	25.03368	25.03368
9/1/2002	21.49319	8.04E-05	19.95112	19.9512	4.84E-05	20.29251	20.29256	4.27E-05	20.39024	20.39028
10/1/2002	19.88199	0.008735	14.29965	14.30839	0.003961	15.10987	15.11383	0.003548	15.28632	15.28987
11/1/2002	14.60778	0.618072	2.513808	3.13188	0.314188	3.255273	3.569461	0.279627	3.448268	3.727895
12/1/2002	9.495833	10.14874	0.196453	10.34519	7.762161	0.343195	8.105356	7.372659	0.389522	7.762181
		46.36152	**112.7181**	**159.0796**	**35.87348**	**115.6889**	**151.5624**	**34.02471**	**116.6181**	**150.6428**

Building Four 20% With Shading

		1E1			1E2			1E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.26082	1.66E-05	12.26084	9.23804	0.000355	9.238395	8.697486	0.000583	8.698069
2/1/2002	8.615029	9.272129	0.013949	9.286078	6.920321	0.033145	6.953466	6.489284	0.041393	6.530677
3/1/2002	9.745699	8.647758	0.103306	8.751064	6.658689	0.177467	6.836156	6.261703	0.201778	6.463481
4/1/2002	13.88528	3.097796	2.11033	5.208126	2.313701	2.499609	4.81331	2.166692	2.617136	4.783828
5/1/2002	19.40779	0.016352	9.998089	10.01444	0.011722	10.44694	10.45866	0.011135	10.58517	10.59631
6/1/2002	20.98195	0.001793	13.63274	13.63453	0.001006	13.99292	13.99393	0.000849	14.10308	14.10393
7/1/2002	22.73441	0	26.00468	26.00468	0	25.93844	25.93844	0	25.98565	25.98565
8/1/2002	23.04382	0	25.32748	25.32748	0	25.29382	25.29382	0	25.3338	25.3338
9/1/2002	21.49319	4.59E-05	20.25392	20.25397	2.18E-05	20.6395	20.63952	1.52E-05	20.74711	20.74713
10/1/2002	19.88199	0.006288	14.61223	14.61852	0.002597	15.49342	15.49602	0.002327	15.68693	15.68926
11/1/2002	14.60778	0.520004	2.72654	3.246544	0.237686	3.593682	3.831368	0.208975	3.823665	4.03264
12/1/2002	9.495833	9.484432	0.240178	9.72461	7.039946	0.422048	7.461994	6.633897	0.480489	7.114386
		43.30742	**115.0235**	**158.3309**	**32.42373**	**118.5313**	**150.9551**	**30.47236**	**119.6068**	**150.0791**

Building Four 20% With Shading

		2C1			2C2			2C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.02715	3E-05	12.02718	9.032785	0.000357	9.033142	8.500225	0.000601	8.500826
2/1/2002	8.615029	9.099079	0.013584	9.112663	6.780811	0.032163	6.812974	6.357429	0.04013	6.397559
3/1/2002	9.745699	8.479576	0.099705	8.579281	6.524602	0.172872	6.697474	6.138293	0.196979	6.335272
4/1/2002	13.88528	3.016392	2.086414	5.102806	2.25236	2.461982	4.714342	2.110522	2.576205	4.686727
5/1/2002	19.40779	0.014558	9.926451	9.941009	0.01058	10.34847	10.35905	0.009816	10.48037	10.49019
6/1/2002	20.98195	0.001629	13.53922	13.54085	0.000928	13.87146	13.87239	0.000779	13.97539	13.97617
7/1/2002	22.73441	0	25.86143	25.86143	0	25.76601	25.76601	0	25.80695	25.80695
8/1/2002	23.04382	0	25.15228	25.15228	0	25.08971	25.08971	0	25.12393	25.12393
9/1/2002	21.49319	3.78E-05	20.08878	20.08882	1.52E-05	20.44131	20.44133	9.08E-06	20.54218	20.54219
10/1/2002	19.88199	0.005544	14.4846	14.49014	0.002334	15.33209	15.33442	0.00209	15.51762	15.51971
11/1/2002	14.60778	0.493061	2.697865	3.190926	0.222792	3.54773	3.770522	0.196372	3.770709	3.967081
12/1/2002	9.495833	9.285803	0.239104	9.524907	6.871994	0.419172	7.291166	6.472618	0.477538	6.950156
		42.42283	**114.1895**	**156.6123**	**31.6992**	**117.4833**	**149.1825**	**29.78815**	**118.5086**	**148.2968**

Building Four 20% With Shading

		2E1			2E2			2E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	11.6228	4.67E-05	11.62285	8.599686	0.000455	8.600141	8.057282	0.000787	8.058069
2/1/2002	8.615029	8.775781	0.015296	8.791077	6.430134	0.036552	6.466686	5.997391	0.045498	6.042889
3/1/2002	9.745699	8.19781	0.108066	8.305876	6.209729	0.187743	6.397472	5.813839	0.214685	6.028524
4/1/2002	13.88528	2.871642	2.153134	5.024776	2.104532	2.555026	4.659558	1.962638	2.67654	4.639178
5/1/2002	19.40779	0.011761	10.08511	10.09687	0.008719	10.52903	10.53775	0.008054	10.66626	10.67431
6/1/2002	20.98195	0.001102	13.70254	13.70364	0.000549	14.0479	14.04845	0.000453	14.15592	14.15637
7/1/2002	22.73441	0	26.0294	26.0294	0	25.94397	25.94397	0	25.98676	25.98676
8/1/2002	23.04382	0	25.25937	25.25937	0	25.20233	25.20233	0	25.2337	25.2337
9/1/2002	21.49319	2.29E-05	20.18218	20.1822	1.53E-06	20.54272	20.54272	0	20.64589	20.64589
10/1/2002	19.88199	0.004487	14.55516	14.55965	0.001805	15.41974	15.42155	0.001594	15.60958	15.61117
11/1/2002	14.60778	0.448732	2.780111	3.228843	0.192687	3.676114	3.868801	0.169282	3.913114	4.082396
12/1/2002	9.495833	8.962198	0.259193	9.221391	6.533223	0.455882	6.989105	6.130685	0.519584	6.650269
		40.89634	**115.1296**	**156.0259**	**30.08107**	**118.5975**	**148.6785**	**28.14122**	**119.6683**	**147.8095**

Building Four 40% No Shading

		1C1			1C2			1C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	14.45673	2.46E-06	14.45673	11.72895	0.000174	11.72912	11.27132	0.000295	11.27162
2/1/2002	8.615029	11.10711	0.007338	11.11445	8.977211	0.015201	8.992412	8.616633	0.018492	8.635125
3/1/2002	9.745699	10.20311	0.057215	10.26032	8.478796	0.098198	8.576994	8.154812	0.111686	8.266498
4/1/2002	13.88528	3.803687	1.735341	5.539028	3.088698	1.992589	5.081287	2.960502	2.069885	5.030387
5/1/2002	19.40779	0.025061	9.46772	9.492781	0.017351	9.819213	9.836564	0.016174	9.925746	9.94192
6/1/2002	20.98195	0.003205	13.24386	13.24706	0.002153	13.56007	13.56222	0.001926	13.65124	13.65317
7/1/2002	22.73441	0	25.63184	25.63184	0	25.55708	25.55708	0	25.59203	25.59203
8/1/2002	23.04382	0	24.6018	24.6018	0	24.53699	24.53699	0	24.55913	24.55913
9/1/2002	21.49319	8.39E-05	19.10283	19.10291	4.94E-05	19.38227	19.38232	4.38E-05	19.46102	19.46106
10/1/2002	19.88199	0.0119	13.3382	13.3501	0.004805	14.02814	14.03294	0.004182	14.17394	14.17812
11/1/2002	14.60778	0.873983	2.101091	2.975074	0.508554	2.633992	3.142546	0.461834	2.765623	3.227457
12/1/2002	9.495833	11.33805	0.138405	11.47646	9.03889	0.233596	9.272486	8.680342	0.263818	8.94416
		51.82292	**109.4256**	**161.2486**	**41.84546**	**111.8575**	**153.703**	**40.16777**	**112.5929**	**152.7607**

Building Four 40% No Shading

		1E1			1E2			1E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.33792	1.5E-05	13.33793	10.49426	0.000319	10.49458	10.00309	0.00054	10.00363
2/1/2002	8.615029	10.15412	0.010565	10.16469	7.914245	0.023696	7.937941	7.521326	0.029322	7.550648
3/1/2002	9.745699	9.359751	0.081315	9.441066	7.478358	0.138208	7.616566	7.114536	0.156557	7.271093
4/1/2002	13.88528	3.404965	1.928183	5.333148	2.634466	2.264794	4.89926	2.493004	2.363948	4.856952
5/1/2002	19.40779	0.017418	9.890073	9.907491	0.012764	10.33416	10.34692	0.011881	10.46178	10.47366
6/1/2002	20.98195	0.001736	13.68536	13.6871	0.000864	14.06325	14.06411	0.000717	14.16839	14.16911
7/1/2002	22.73441	0	26.04657	26.04657	0	26.01689	26.01689	0	26.06326	26.06326
8/1/2002	23.04382	0	24.97025	24.97025	0	24.9432	24.9432	0	24.97472	24.97472
9/1/2002	21.49319	4.54E-05	19.58059	19.58064	2.14E-05	19.923	19.92302	1.49E-05	20.01538	20.01539
10/1/2002	19.88199	0.007437	13.83981	13.84725	0.002729	14.6408	14.64353	0.002414	14.81074	14.81315
11/1/2002	14.60778	0.690687	2.352129	3.042816	0.339078	3.020689	3.359767	0.297431	3.192462	3.489893
12/1/2002	9.495833	10.35564	0.18526	10.5409	7.977442	0.315519	8.292961	7.595381	0.357124	7.952505
		47.32972	**112.5701**	**159.8998**	**36.85423**	**115.6845**	**152.5388**	**35.03979**	**116.5942**	**151.634**

Building Four 40% No Shading

		2C1			2C2			2C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.06023	2.64E-05	13.06026	10.22482	0.000329	10.22515	9.743218	0.000533	9.743751
2/1/2002	8.615029	9.93242	0.010142	9.942562	7.740363	0.022472	7.762835	7.3569	0.027746	7.384646
3/1/2002	9.745699	9.177238	0.07518	9.252418	7.34647	0.129402	7.475872	6.996549	0.147201	7.14375
4/1/2002	13.88528	3.328906	1.869968	5.198874	2.58942	2.180877	4.770297	2.455319	2.274157	4.729476
5/1/2002	19.40779	0.015814	9.684333	9.700147	0.011946	10.07449	10.08644	0.011141	10.19068	10.20182
6/1/2002	20.98195	0.0017	13.43112	13.43282	0.000853	13.75628	13.75713	0.000741	13.85218	13.85292
7/1/2002	22.73441	0	25.71455	25.71455	0	25.62879	25.62879	0	25.66415	25.66415
8/1/2002	23.04382	0	24.64689	24.64689	0	24.57017	24.57017	0	24.59221	24.59221
9/1/2002	21.49319	3.83E-05	19.30154	19.30158	1.6E-05	19.59181	19.59183	9.96E-06	19.67432	19.67433
10/1/2002	19.88199	0.00643	13.65591	13.66234	0.002437	14.40408	14.40652	0.002172	14.5619	14.56407
11/1/2002	14.60778	0.653534	2.319331	2.972865	0.320048	2.961916	3.281964	0.281654	3.125284	3.406938
12/1/2002	9.495833	10.08471	0.183471	10.26818	7.752196	0.311899	8.064095	7.378812	0.352792	7.731604
		46.26102	**110.8925**	**157.1535**	**35.98857**	**113.6325**	**149.6211**	**34.22652**	**114.4632**	**148.6897**

Building Four 40% No Shading										
		2E1			2E2			2E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.47294	4.42E-05	12.47298	9.60459	0.000407	9.604997	9.110764	0.00066	9.111424
2/1/2002	8.615029	9.470847	0.012062	9.482909	7.244969	0.027256	7.272225	6.851431	0.033642	6.885073
3/1/2002	9.745699	8.776652	0.085284	8.861936	6.895916	0.147236	7.043152	6.53345	0.167439	6.700889
4/1/2002	13.88528	3.140043	1.951454	5.091497	2.389322	2.292462	4.681784	2.253542	2.392925	4.646467
5/1/2002	19.40779	0.013069	9.845579	9.858648	0.010094	10.25985	10.26994	0.00935	10.38123	10.39058
6/1/2002	20.98195	0.001028	13.58101	13.58204	0.000522	13.91981	13.92033	0.000414	14.01829	14.0187
7/1/2002	22.73441	0	25.86637	25.86637	0	25.78837	25.78837	0	25.82605	25.82605
8/1/2002	23.04382	0	24.74779	24.74779	0	24.67061	24.67061	0	24.6939	24.6939
9/1/2002	21.49319	2.32E-05	19.44635	19.44637	1.84E-06	19.74993	19.74993	0	19.83492	19.83492
10/1/2002	19.88199	0.004905	13.81402	13.81893	0.00184	14.59047	14.59231	0.001628	14.75521	14.75684
11/1/2002	14.60778	0.571681	2.429748	3.001429	0.258832	3.131233	3.390065	0.226163	3.312339	3.538502
12/1/2002	9.495833	9.594805	0.208042	9.802847	7.241342	0.354743	7.596085	6.862187	0.401973	7.26416
		44.04599	**111.9878**	**156.0337**	**33.64743**	**114.9324**	**148.5798**	**31.84893**	**115.8186**	**147.6675**

Building Four 40% with Shading										
		1C1			1C2			1C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	14.13015	2.49E-06	14.13015	11.39624	0.000175	11.39641	10.93692	0.000295	10.93722
2/1/2002	8.615029	10.88939	0.007636	10.89703	8.754049	0.015847	8.769896	8.393168	0.019379	8.412547
3/1/2002	9.745699	10.20936	0.060076	10.26944	8.473011	0.101739	8.57475	8.146228	0.115556	8.261784
4/1/2002	13.88528	3.857254	1.726239	5.583493	3.141353	1.975599	5.116952	3.012643	2.050809	5.063452
5/1/2002	19.40779	0.030063	9.072717	9.10278	0.01927	9.36331	9.38258	0.017797	9.459299	9.477096
6/1/2002	20.98195	0.003285	12.68959	12.69288	0.002249	12.93926	12.94151	0.002022	13.02153	13.02355
7/1/2002	22.73441	0	24.95192	24.95192	0	24.80112	24.80112	0	24.82629	24.82629
8/1/2002	23.04382	0	24.32432	24.32432	0	24.20857	24.20857	0	24.22534	24.22534
9/1/2002	21.49319	8.44E-05	19.14878	19.14886	5.05E-05	19.40163	19.40168	4.49E-05	19.4766	19.47664
10/1/2002	19.88199	0.011945	13.60395	13.6159	0.004879	14.28673	14.29161	0.004253	14.43085	14.4351
11/1/2002	14.60778	0.789699	2.235116	3.024815	0.451831	2.80644	3.258271	0.40963	2.946796	3.356426
12/1/2002	9.495833	11.06339	0.151153	11.21454	8.775588	0.25613	9.031718	8.419623	0.289183	8.708806
		50.98462	**107.9715**	**158.9561**	**41.01852**	**110.1565**	**151.1751**	**39.34233**	**110.8619**	**150.2043**

Building Four 40% with Shading										
		1E1			1E2			1E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.03189	1.5E-05	13.0319	10.18556	0.000318	10.18588	9.694411	0.000547	9.694958
2/1/2002	8.615029	9.940752	0.011081	9.951833	7.703354	0.024887	7.728241	7.311548	0.030811	7.342359
3/1/2002	9.745699	9.335426	0.083937	9.419363	7.459206	0.141499	7.600705	7.097664	0.160099	7.257763
4/1/2002	13.88528	3.439616	1.920855	5.360471	2.68072	2.241456	4.922176	2.541655	2.336264	4.877919
5/1/2002	19.40779	0.018943	9.517975	9.536918	0.013297	9.895689	9.908986	0.01224	10.01369	10.02593
6/1/2002	20.98195	0.001953	13.17531	13.17726	0.001131	13.4885	13.48963	0.000956	13.58477	13.58573
7/1/2002	22.73441	0	25.44673	25.44673	0	25.3425	25.3425	0	25.38008	25.38008
8/1/2002	23.04382	0	24.75596	24.75596	0	24.67815	24.67815	0	24.70586	24.70586
9/1/2002	21.49319	4.65E-05	19.65804	19.65809	2.28E-05	19.97339	19.97341	1.63E-05	20.06158	20.0616
10/1/2002	19.88199	0.007554	14.12444	14.13199	0.002783	14.91331	14.91609	0.00245	15.08	15.08245
11/1/2002	14.60778	0.625117	2.496516	3.121633	0.306552	3.209392	3.515944	0.270115	3.391083	3.661198
12/1/2002	9.495833	10.1156	0.201913	10.31751	7.755292	0.342906	8.098198	7.377949	0.387321	7.76527
		46.5169	**111.3928**	**157.9097**	**36.10792**	**114.252**	**150.3599**	**34.309**	**115.1321**	**149.4411**

Building Four 40% with Shading										
		2C1			2C2			2C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.74148	2.63E-05	12.74151	9.903774	0.000329	9.904103	9.421984	0.000532	9.422516
2/1/2002	8.615029	9.68439	0.010669	9.695059	7.493384	0.023823	7.517207	7.110505	0.029365	7.13987
3/1/2002	9.745699	9.068866	0.079007	9.147873	7.237586	0.135028	7.372614	6.887521	0.153463	7.040984
4/1/2002	13.88528	3.315211	1.888165	5.203376	2.583733	2.192675	4.776408	2.450645	2.284366	4.735011
5/1/2002	19.40779	0.017079	9.425214	9.442293	0.012349	9.767186	9.779535	0.011393	9.876369	9.887762
6/1/2002	20.98195	0.001762	13.04562	13.04738	0.001007	13.32194	13.32295	0.000848	13.4109	13.41175
7/1/2002	22.73441	0	25.25298	25.25298	0	25.11077	25.11077	0	25.13887	25.13887
8/1/2002	23.04382	0	24.52556	24.52556	0	24.41	24.41	0	24.42724	24.42724
9/1/2002	21.49319	3.89E-05	19.44725	19.44729	1.68E-05	19.7202	19.72022	1.08E-05	19.79992	19.79993
10/1/2002	19.88199	0.006494	13.97676	13.98325	0.002456	14.72135	14.72381	0.002188	14.87812	14.88031
11/1/2002	14.60778	0.589161	2.459724	3.048885	0.286607	3.145597	3.432204	0.253004	3.319215	3.572219
12/1/2002	9.495833	9.847961	0.199889	10.04785	7.531413	0.339181	7.870594	7.162129	0.382355	7.544484
		45.27244	**110.3109**	**155.5833**	**35.05233**	**112.8881**	**147.9404**	**33.30023**	**113.7007**	**147.0009**

Building Four 40% with Shading										
		2E1			2E2			2E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.19036	4.39E-05	12.1904	9.322379	0.000405	9.322784	8.829013	0.000653	8.829666
2/1/2002	8.615029	9.237782	0.012692	9.250474	7.014645	0.028573	7.043218	6.621759	0.035202	6.656961
3/1/2002	9.745699	8.630971	0.089489	8.72046	6.755986	0.153377	6.909363	6.394414	0.174581	6.568995
4/1/2002	13.88528	3.110095	1.976598	5.086693	2.369765	2.311634	4.681399	2.235611	2.410707	4.646318
5/1/2002	19.40779	0.014189	9.643243	9.657432	0.010028	10.01492	10.02495	0.009265	10.1316	10.14086
6/1/2002	20.98195	0.001187	13.25571	13.2569	0.000568	13.5489	13.54947	0.000471	13.64236	13.64283
7/1/2002	22.73441	0	25.46036	25.46036	0	25.33001	25.33001	0	25.36126	25.36126
8/1/2002	23.04382	0	24.6565	24.6565	0	24.54844	24.54844	0	24.56674	24.56674
9/1/2002	21.49319	2.37E-05	19.61759	19.61761	2.29E-06	19.90426	19.90426	0	19.9873	19.9873
10/1/2002	19.88199	0.004927	14.13149	14.13642	0.00185	14.90348	14.90533	0.001635	15.06685	15.06848
11/1/2002	14.60778	0.518798	2.570559	3.089357	0.234014	3.315696	3.54971	0.205605	3.507068	3.712673
12/1/2002	9.495833	9.392723	0.22476	9.617483	7.055753	0.381814	7.437567	6.680434	0.431394	7.111828
		43.10106	**111.639**	**154.7401**	**32.76499**	**114.4415**	**147.2065**	**30.97821**	**115.3157**	**146.2939**

Building Four 100% No Shading										
		1C1			1C2			1C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	15.73401	1.63E-06	15.73401	13.4274	0.000146	13.42755	13.0893	0.000253	13.08955
2/1/2002	8.615029	11.93727	0.006613	11.94388	10.15469	0.01289	10.16758	9.889058	0.015504	9.904562
3/1/2002	9.745699	10.5081	0.064153	10.57225	9.126883	0.095409	9.222292	8.898777	0.104967	9.003744
4/1/2002	13.88528	3.864136	1.940826	5.804962	3.295125	2.135439	5.430564	3.207382	2.189316	5.396698
5/1/2002	19.40779	0.0266	10.66369	10.69029	0.019394	10.96924	10.98863	0.018238	11.04582	11.06406
6/1/2002	20.98195	0.002873	14.67256	14.67543	0.001754	14.95209	14.95384	0.001517	15.01787	15.01939
7/1/2002	22.73441	0	27.50739	27.50739	0	27.4664	27.4664	0	27.48872	27.48872
8/1/2002	23.04382	0	25.87803	25.87803	0	25.81736	25.81736	0	25.82597	25.82597
9/1/2002	21.49319	0.000102	19.78296	19.78306	6.35E-05	19.96931	19.96937	5.41E-05	20.0102	20.01025
10/1/2002	19.88199	0.02068	13.49236	13.51304	0.012311	13.99927	14.01158	0.011381	14.08844	14.09982
11/1/2002	14.60778	1.090697	1.99863	3.089327	0.790263	2.396999	3.187262	0.758902	2.487495	3.246397
12/1/2002	9.495833	12.53315	0.120195	12.65334	10.58031	0.189718	10.77003	10.31317	0.210533	10.5237
		55.71762	**116.1274**	**171.845**	**47.40819**	**118.0043**	**165.4125**	**46.18778**	**118.4851**	**164.6729**

Building Four 100% No Shading

		1E1			1E2			1E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.70883	1.52E-05	13.70885	11.28422	0.000305	11.28452	10.90768	0.000511	10.90819
2/1/2002	8.615029	10.20567	0.011367	10.21704	8.31811	0.021903	8.340013	8.029712	0.026159	8.055871
3/1/2002	9.745699	8.986899	0.110184	9.097083	7.413362	0.160813	7.574175	7.144916	0.175001	7.319917
4/1/2002	13.88528	3.148297	2.359836	5.508133	2.515061	2.667133	5.182194	2.414864	2.745137	5.160001
5/1/2002	19.40779	0.015694	11.65381	11.6695	0.012067	12.10267	12.11474	0.011199	12.20363	12.21483
6/1/2002	20.98195	0.001234	15.66563	15.66686	0.000635	16.05987	16.06051	0.000517	16.14471	16.14523
7/1/2002	22.73441	0	28.46073	28.46073	0	28.50839	28.50839	0	28.54937	28.54937
8/1/2002	23.04382	0	26.73603	26.73603	0	26.749	26.749	0	26.76945	26.76945
9/1/2002	21.49319	4.57E-05	20.80999	20.81004	1.39E-05	21.09793	21.09794	7.47E-06	21.15127	21.15128
10/1/2002	19.88199	0.0082	14.5353	14.5435	0.003112	15.20433	15.20744	0.002741	15.32003	15.32277
11/1/2002	14.60778	0.712865	2.427722	3.140587	0.413224	2.979059	3.392283	0.383064	3.105541	3.488605
12/1/2002	9.495833	10.75263	0.184625	10.93725	8.710161	0.288807	8.998968	8.427566	0.318607	8.746173
		47.54036	**122.9552**	**170.4956**	**38.66997**	**125.8402**	**164.5102**	**37.32227**	**126.5094**	**163.8317**

Building Four 100% No Shading

		2C1			2C2			2C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.42858	2.33E-05	13.4286	11.07937	0.00029	11.07966	10.72564	0.000483	10.72612
2/1/2002	8.615029	10.03501	0.009922	10.04493	8.222559	0.019146	8.241705	7.945438	0.022822	7.96826
3/1/2002	9.745699	8.882321	0.093345	8.975666	7.3984	0.137483	7.535883	7.148915	0.150581	7.299496
4/1/2002	13.88528	3.128041	2.177431	5.305472	2.533815	2.433243	4.967058	2.440831	2.501418	4.942249
5/1/2002	19.40779	0.015111	11.09242	11.10753	0.011713	11.45139	11.4631	0.010953	11.53674	11.54769
6/1/2002	20.98195	0.001266	15.04738	15.04865	0.000692	15.35641	15.3571	0.000573	15.42794	15.42851
7/1/2002	22.73441	0	27.66638	27.66638	0	27.62365	27.62365	0	27.64786	27.64786
8/1/2002	23.04382	0	26.03681	26.03681	0	25.97346	25.97346	0	25.98258	25.98258
9/1/2002	21.49319	4.14E-05	20.1992	20.19924	1.17E-05	20.40303	20.40304	5.85E-06	20.44527	20.44528
10/1/2002	19.88199	0.007195	14.09997	14.10717	0.002835	14.68218	14.68502	0.002515	14.78236	14.78488
11/1/2002	14.60778	0.691469	2.323578	3.015047	0.411106	2.826697	3.237803	0.383924	2.940852	3.324776
12/1/2002	9.495833	10.50794	0.1728	10.68074	8.533502	0.269101	8.802603	8.260879	0.297441	8.55832
		46.69697	**118.9193**	**165.6162**	**38.194**	**121.1761**	**159.3701**	**36.91967**	**121.7363**	**158.656**

Building Four 100% No Shading

		2E1			2E2			2E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.5632	4.29E-05	12.56324	10.14558	0.00038	10.14596	9.763826	0.000602	9.764428
2/1/2002	8.615029	9.312607	0.013629	9.326236	7.466572	0.025412	7.491984	7.179157	0.030021	7.209178
3/1/2002	9.745699	8.248137	0.111784	8.359921	6.699294	0.164671	6.863965	6.436023	0.180352	6.616375
4/1/2002	13.88528	2.841448	2.322375	5.163823	2.233294	2.619356	4.85265	2.138132	2.696701	4.834833
5/1/2002	19.40779	0.012528	11.36368	11.37621	0.009552	11.75886	11.76841	0.008933	11.85185	11.86078
6/1/2002	20.98195	0.000825	15.29177	15.2926	0.000365	15.6224	15.62276	0.000282	15.69797	15.69825
7/1/2002	22.73441	0	27.8549	27.8549	0	27.82388	27.82388	0	27.85136	27.85136
8/1/2002	23.04382	0	26.19525	26.19525	0	26.13531	26.13531	0	26.14517	26.14517
9/1/2002	21.49319	1.75E-05	20.44163	20.44165	0	20.66884	20.66884	0	20.71803	20.71803
10/1/2002	19.88199	0.004608	14.40157	14.40618	0.001854	15.02411	15.02596	0.001644	15.13193	15.13357
11/1/2002	14.60778	0.554452	2.512977	3.067429	0.290201	3.083075	3.373276	0.266203	3.210861	3.477064
12/1/2002	9.495833	9.745937	0.207861	9.953798	7.751754	0.321654	8.073408	7.472037	0.355082	7.827119
		43.28376	**120.7175**	**164.0012**	**34.59847**	**123.2479**	**157.8464**	**33.26624**	**123.8699**	**157.1362**

Building Four 100% with Shading										
		1C1			1C2			1C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	16.18499	1.55E-06	16.18499	13.84564	0.000144	13.84578	13.50319	0.000251	13.50344
2/1/2002	8.615029	12.53904	0.006471	12.54551	10.72048	0.012657	10.73314	10.45032	0.015236	10.46556
3/1/2002	9.745699	11.50276	0.049078	11.55184	10.09858	0.076901	10.17548	9.867143	0.08572	9.952863
4/1/2002	13.88528	4.479142	1.621009	6.100151	3.901572	1.779863	5.681435	3.811686	1.82838	5.640066
5/1/2002	19.40779	0.044737	9.068784	9.113521	0.037321	9.25264	9.289961	0.035744	9.311143	9.346887
6/1/2002	20.98195	0.003569	12.85612	12.85969	0.002451	13.01971	13.02216	0.00221	13.07022	13.07243
7/1/2002	22.73441	0	25.27595	25.27595	0	25.0826	25.0826	0	25.08603	25.08603
8/1/2002	23.04382	0	24.33726	24.33726	0	24.16057	24.16057	0	24.15248	24.15248
9/1/2002	21.49319	8.97E-05	18.77622	18.77631	5.44E-05	18.88279	18.88284	4.8E-05	18.91474	18.91479
10/1/2002	19.88199	0.027859	13.08705	13.11491	0.016966	13.54538	13.56235	0.015882	13.62767	13.64355
11/1/2002	14.60778	1.19748	1.960826	3.158306	0.887369	2.352965	3.240334	0.855026	2.442664	3.29769
12/1/2002	9.495833	12.84384	0.118332	12.96217	10.8674	0.186793	11.05419	10.59789	0.207354	10.80524
		58.82351	**107.1571**	**165.9806**	**50.37783**	**108.353**	**158.7308**	**49.13914**	**108.7419**	**157.881**

Building Four 100% with Shading										
		1E1			1E2			1E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	14.19526	1.37E-05	14.19527	11.74381	0.000292	11.7441	11.37509	0.000493	11.37558
2/1/2002	8.615029	10.83157	0.010034	10.8416	8.916459	0.019595	8.936054	8.625594	0.023571	8.649165
3/1/2002	9.745699	9.991153	0.082085	10.07324	8.435319	0.124439	8.559758	8.171935	0.137335	8.30927
4/1/2002	13.88528	3.735379	1.931019	5.666398	3.101181	2.16958	5.270761	3.001481	2.235242	5.236723
5/1/2002	19.40779	0.022533	9.877085	9.899618	0.01583	10.16751	10.18334	0.014776	10.246	10.26078
6/1/2002	20.98195	0.001851	13.73246	13.73431	0.001065	13.97967	13.98073	0.000892	14.04525	14.04614
7/1/2002	22.73441	0	26.15249	26.15249	0	26.02453	26.02453	0	26.03908	26.03908
8/1/2002	23.04382	0	25.1225	25.1225	0	25.00071	25.00071	0	25.00276	25.00276
9/1/2002	21.49319	4.54E-05	19.70958	19.70963	2.25E-05	19.89767	19.89769	1.63E-05	19.94283	19.94285
10/1/2002	19.88199	0.011126	13.9822	13.99333	0.00451	14.57666	14.58117	0.003996	14.68283	14.68683
11/1/2002	14.60778	0.806945	2.329802	3.136747	0.498305	2.846481	3.344786	0.466627	2.964479	3.431106
12/1/2002	9.495833	11.08618	0.175215	11.26139	9.02621	0.274433	9.300643	8.741722	0.303584	9.045306
		50.68204	**113.1045**	**163.7865**	**41.74271**	**115.0816**	**156.8243**	**40.40213**	**115.6235**	**156.0256**

Building Four 100% with Shading										
		2C1			2C2			2C3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	13.66305	2.23E-05	13.66307	11.28613	0.000284	11.28641	10.92937	0.000476	10.92985
2/1/2002	8.615029	10.39068	0.009208	10.39989	8.549879	0.017962	8.567841	8.269516	0.021446	8.290962
3/1/2002	9.745699	9.556697	0.072881	9.629578	8.066232	0.111708	8.17794	7.814157	0.123709	7.937866
4/1/2002	13.88528	3.541358	1.854083	5.395441	2.943514	2.066323	5.009837	2.849981	2.126405	4.976386
5/1/2002	19.40779	0.019923	9.626084	9.646007	0.014679	9.85907	9.873749	0.013695	9.927621	9.941316
6/1/2002	20.98195	0.00183	13.42302	13.42485	0.001085	13.61173	13.61282	0.000921	13.66824	13.66916
7/1/2002	22.73441	0	25.70742	25.70742	0	25.51769	25.51769	0	25.52246	25.52246
8/1/2002	23.04382	0	24.68482	24.68482	0	24.50508	24.50508	0	24.50136	24.50136
9/1/2002	21.49319	3.96E-05	19.32145	19.32149	1.84E-05	19.44787	19.44789	1.27E-05	19.48268	19.48269
10/1/2002	19.88199	0.00956	13.69751	13.70707	0.003919	14.22658	14.2305	0.003474	14.32026	14.32373
11/1/2002	14.60778	0.749384	2.267655	3.017039	0.463401	2.754571	3.217972	0.435721	2.864988	3.300709
12/1/2002	9.495833	10.65361	0.168018	10.82163	8.661034	0.26178	8.922814	8.386276	0.289288	8.675564
		48.58613	**110.8322**	**159.4183**	**39.98989**	**112.3806**	**152.3705**	**38.70312**	**112.8489**	**151.5521**

Building Four 100% with Shading										
		2E1			2E2			2E3		
Date/Time	OutsideTemp	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total	Heat (Oil)	Chiller	Total
	°C	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2	kWh/m2
1/1/2002	8.013307	12.72044	4.07E-05	12.72048	10.28047	0.000373	10.28084	9.914325	0.000589	9.914914
2/1/2002	8.615029	9.597004	0.012108	9.609112	7.731631	0.022827	7.754458	7.44287	0.026998	7.469868
3/1/2002	9.745699	8.845834	0.088935	8.934769	7.30414	0.135262	7.439402	7.041645	0.149697	7.191342
4/1/2002	13.88528	3.199409	1.989739	5.189148	2.591197	2.234087	4.825284	2.496338	2.301246	4.797584
5/1/2002	19.40779	0.014634	9.935231	9.949865	0.0109	10.20033	10.21123	0.01013	10.27542	10.28555
6/1/2002	20.98195	0.001246	13.74002	13.74127	0.000568	13.94812	13.94869	0.000458	14.00802	14.00848
7/1/2002	22.73441	0	25.99155	25.99155	0	25.81367	25.81367	0	25.82008	25.82008
8/1/2002	23.04382	0	24.90623	24.90623	0	24.73223	24.73223	0	24.7258	24.7258
9/1/2002	21.49319	2.37E-05	19.62166	19.62168	2.85E-06	19.76321	19.76321	0	19.80116	19.80116
10/1/2002	19.88199	0.005782	14.01259	14.01837	0.002116	14.58135	14.58347	0.001887	14.68156	14.68345
11/1/2002	14.60778	0.598271	2.446988	3.045259	0.329529	2.995728	3.325257	0.304283	3.119869	3.424152
12/1/2002	9.495833	9.836558	0.203771	10.04033	7.830252	0.315321	8.145573	7.550034	0.348076	7.89811
		44.8192	**112.9489**	**157.7681**	**36.08081**	**114.7425**	**150.8233**	**34.76197**	**115.2585**	**150.0205**

تعظيم الطاقة التشغيلية للمباني المائلة حسب توجيهها الجغرافي في عمان، الأردن

إعداد
تالا سمير محمد عوض الله

المشرف
الأستاذ الدكتور مجدي توفيق سعد

ملخـــــــــــص

تركز الدراسة على إيجاد التوصيات المثلى للتصميم المعماري لواجهات المباني المائلة في مدينة عمان، الأردن. وعليه تم اختيار أربعة مبانٍ مائلة واقعية، واجهاتها الرئيسية متجهة لأربعة اتجاهات نصف رئيسية هي الاتجاه الجنوبي الشرقي والجنوبي الغربي والشمالي الشرقي والشمالي الغربي، ليتم نمذجتها حراريا باستخدام برنامج المحاكاة الحاسوبية DesignBuilder®. وبناء على استنتاجات الدراسات السابقة للدراسة، تم اختيار خمسة معايير تصميمية لاختبار أداءها الحراري بالنسبة للاتجاهات الأربعة التي تم ذكرها سابقا. هذه المعايير هي: نسبة مساحة النوافذ إلى مساحة الجدار الخارجي الرئيسي (٢٠ و٤٠ و١٠٠ بالمائة)، والزجاج الشفاف تماما وقليل الانبعاثية، والزجاج المفرد والمزدوج، وخصائص العازل الحراري في غلاف المبنى ووجوده، بالإضافة إلى توفر وسائل التظليل وعدمه. من النتائج التي تم الحصول عليها من محاكاة ٧٢ حالة دراسية لكل مبنى، وبمجموع ٢٨٨ حالة دراسية، يمكن إدراج التوصيات التالية بالنسبة للمباني المائلة في مدينة عمان:

١) إن استخدام الزجاج المزدوج له نتيجة ايجابية دائما في التوفير من استخدام الطاقة اللازمة للتدفئة أو التكييف، بغض النظر عن اتجاه الواجهة الرئيسية للمباني المائلة.

٢) لا تتطلب الواجهات الرئيسية للمباني المائلة المتجهة للاتجاه الشمالي الغربي أو الشمالي الشرقي إلى وسائل تظليل، بينما تتطلب الواجهات الرئيسية المتجهة إلى الجنوب الشرقي والتي تكون نسبة مساحة النوافذ إلى مساحة الجدار فيها عالية إلى ضرورة وجود وسائل التظليل.

٣) يجب على جميع المباني المائلة في مدينة عمان أن تحقق المتطلبات الدنيا اللازمة في العزل الحراري لغلاف المبنى والواردة في كودة المباني الموفرة للطاقة الأردنية، بغض النظر عن الاتجاه الذي تتجه في الواجهة الرئيسية

٤) يجب اتخاذ الإجراءات اللازمة لمنع استخدام الزجاج المفرد الشفاف في الواجهات الرئيسية التي تكون نسبة مساحة النوافذ إلى مساحة الجدار فيها ١٠٠ بالمائة والمتجهة إلى الاتجاه الشمالي الشرقي أو الشمالي الغربي. بينما تعتبر نسبة مساحة النوافذ إلى مساحة الجدار المثلى للواجهات الرئيسية في المباني المائلة هي ٤٠ بالمائة بغض النظر عن الاتجاه.